6-17-2004

SLIDES: The Spokane and the Yakima: A Tale of Two Aquifers

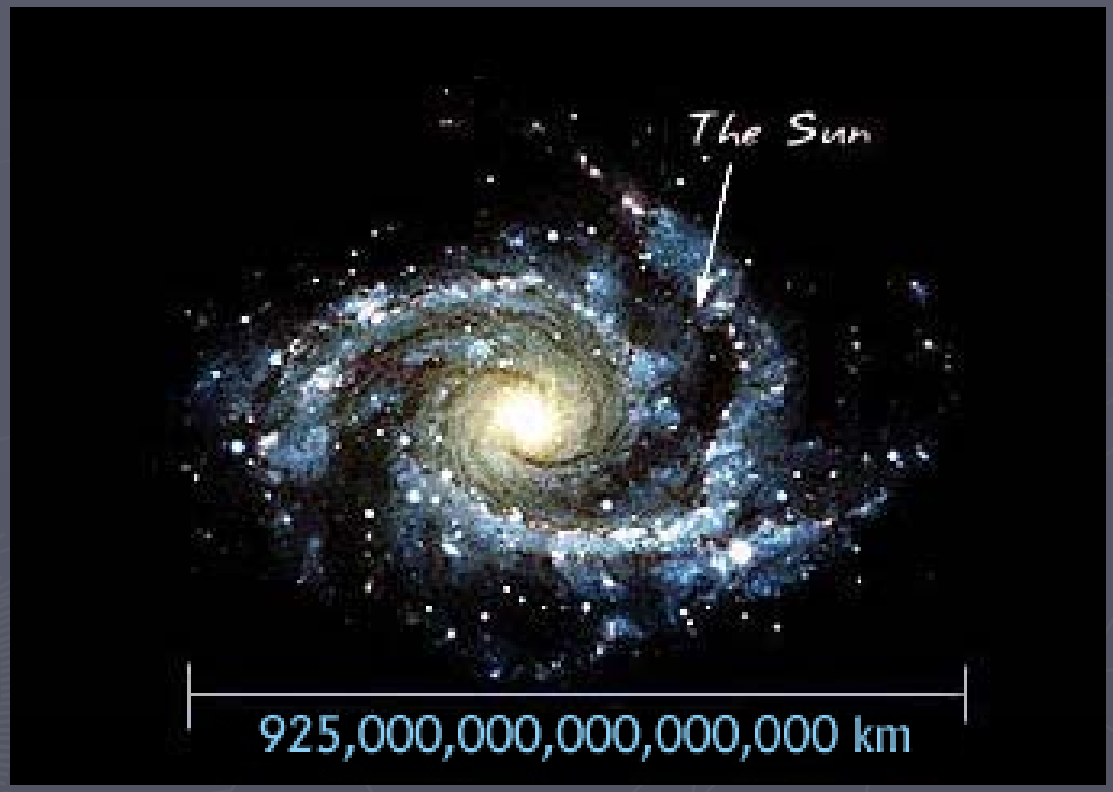
Rachel Paschal Osborn

Rachel Paschal Osborn, *The Spokane and the Yakima: A Tale of Two Aquifers*, *in* GROUNDWATER IN THE WEST (Natural Res. Law Ctr., Univ. of Colo. Sch. of Law, 2004).

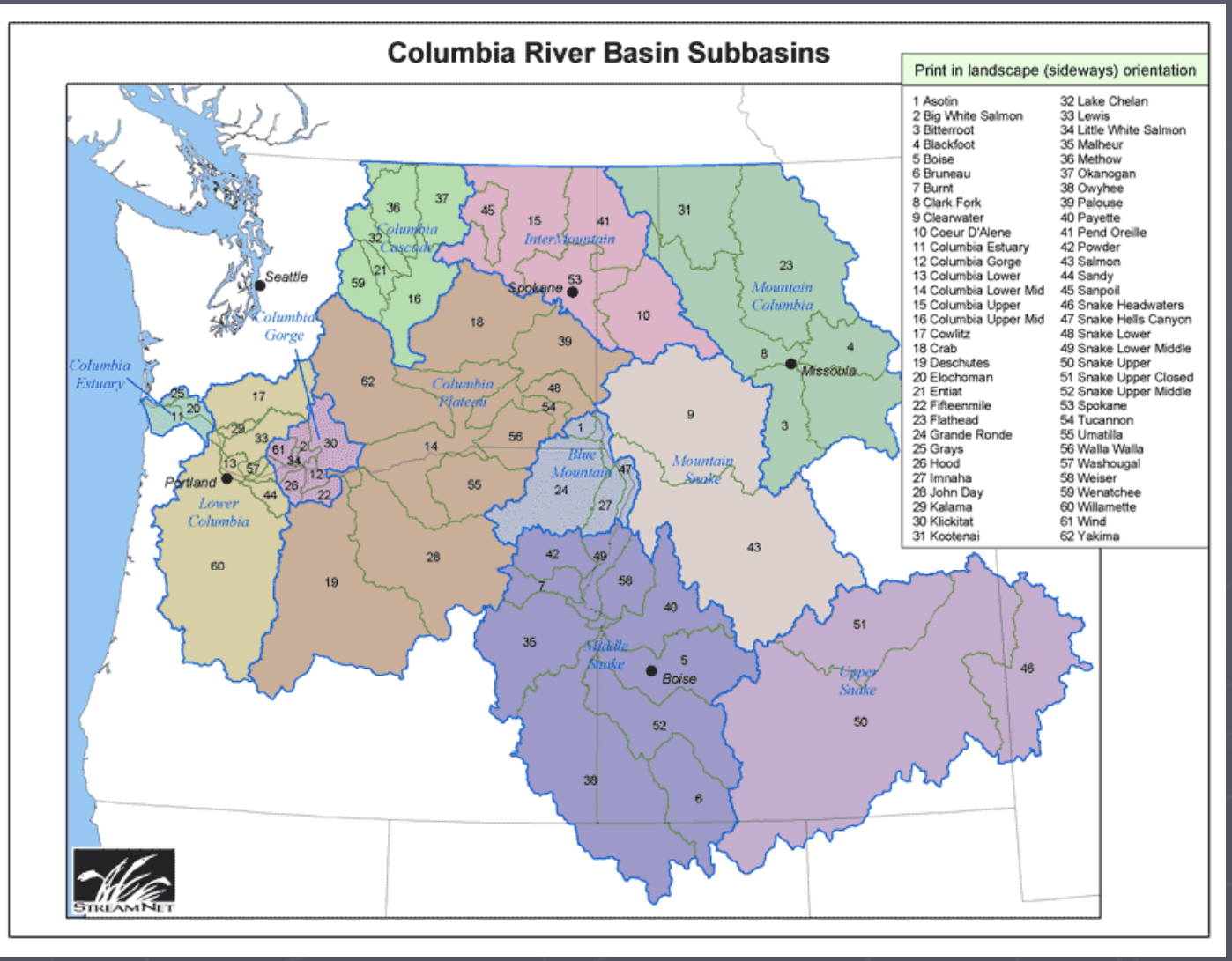
The Spokane and the Yakima: A Tale of Two Aquifers

It was the best of travel times . . .

It was the worst of travel times . . .



- NASA (2003)


Columbia River Basin Subbasins
Print in landscape (sideways) orientation
1 Asotin
2 Big White Salmon
3 Bitterroot
4 Blackfoot
5 Boise
6 Bruneau
7 Burnt
8 Clark Fork
9 Clearwater
10 Coeur D'Alene
11 Columbia Estuary
12 Columbia Gorge
13 Columbia Lower
14 Columbia Lower Mid
15 Columbia Upper
16 Columbia Upper Mid
17 Cowlitz
18 Crab
19 Deschutes
20 Elochoman
21 Entiat
22 Fifteenmile
23 Flathead
24 Grande Ronde
25 Grays
26 Hood
27 Imnaha
28 John Day
29 Kalama
30 Klickitat
31 Kootenai
32 Lake Chelan
33 Lewis
34 Little White Salmon
35 Malheur
36 Methow
37 Okanogan
38 Owyhee
39 Palouse
40 Payette
41 Pend Oreille
42 Powder
43 Salmon
44 Sandy
45 Sanpoil
46 Snake Headwaters
47 Snake Hells Canyon
48 Snake Lower
49 Snake Lower Middle
50 Snake Upper
51 Snake Upper Closed
52 Snake Upper Middle
53 Spokane
54 Tucannon
55 Umatilla
56 Walla Walla
57 Washougal
58 Weiser
59 Wenatchee
60 Willamette
61 Wind
62 Yakima
Seattle
Spokane
Missoula
Portland
Boise
Columbia Cascade
InterMountain
Mountain Columbia
Columbia Gorge
Columbia Estuary
Columbia Plateau
Blue Mountain
Mountain Snake
Lower Columbia
Middle Snake
Upper Snake
StreamNet

Yakima River Basin

The Obligatory Disclaimer

- I am not the Yakama Nation, but I work there, in service of the unholy union between the laws of nature and the laws of man

The Laws of Nature
A two-minute short course

- First Quiz
- Inflow = O_____ + Change in S_____

Continuity Equation (Conservation of Mass)

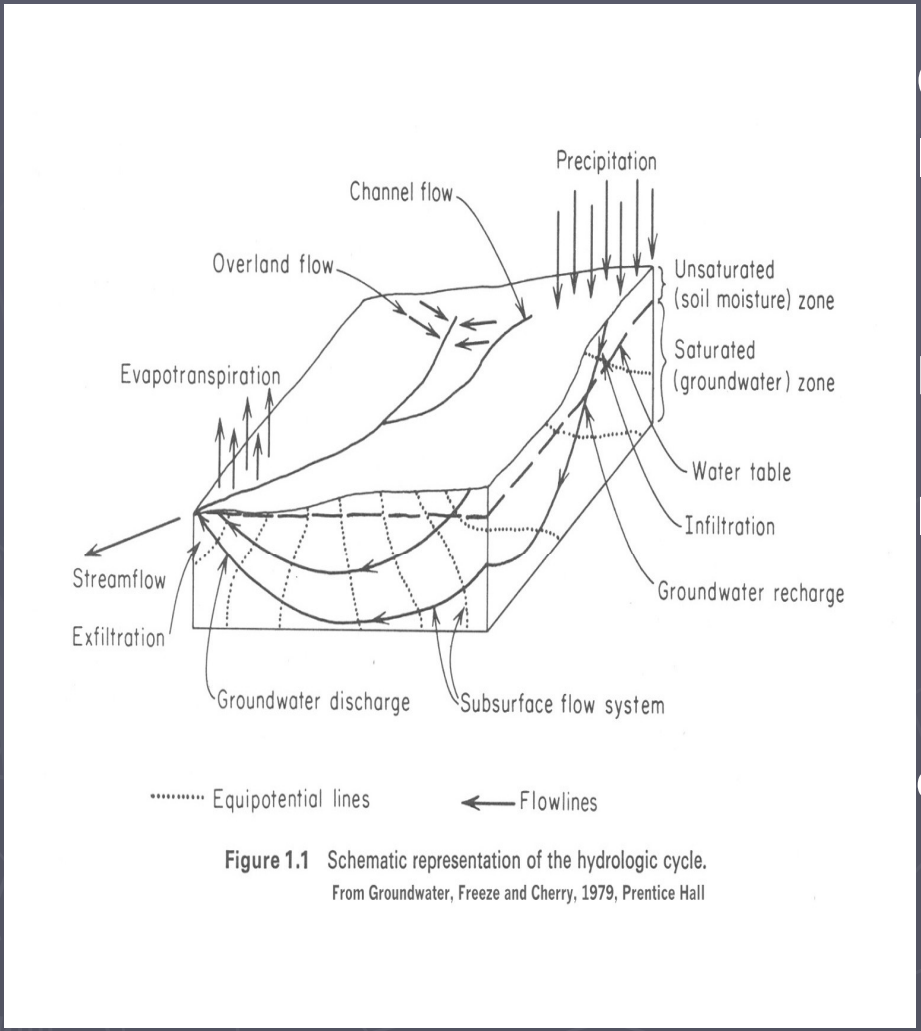


Figure 1.1 Schematic representation of the hydrologic cycle.
From Groundwater, Freeze and Cherry, 1979, Prentice Hall

Continuity Equation:

Inflow equals outflow plus change in storage

For saturated zone flow in an aquifer system:

Recharge to saturated zone from surface sources

=

discharge from saturated zone to surface water or atmosphere

+

change in amount of water stored in aquifer system

Darcy's Law

$$Q = -KA\frac{h_2 - h_1}{\ell_2 - \ell_1}$$

Volumetric rate of flow through porous media equals hydraulic conductivity (aka permeability) times cross sectional area times drop in head divided by length along flow path

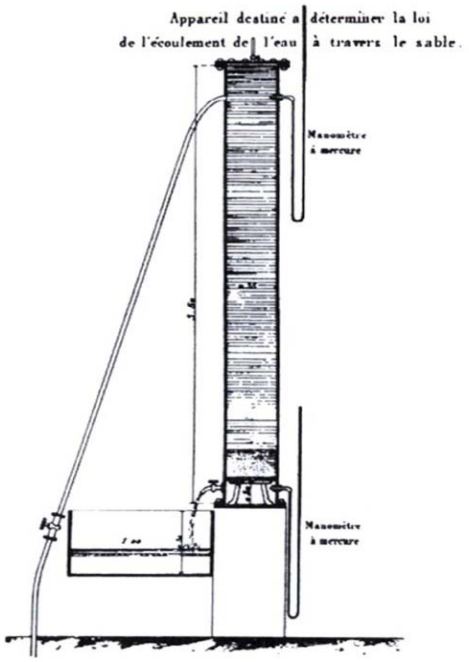


Figure 1.2
Darcy's experimental sand column. (From Hubbert, 1969. © 1956, Society of Petroleum Engineers of AIME, published *JPT*, Oct. 1956; *Trans.* AIME, 1956. Facsimile of Fig. 3 in Darcy, Henry, *Les Fontaines de la Ville de Dijon*, Victor Dalmont, Paris, 1856.)

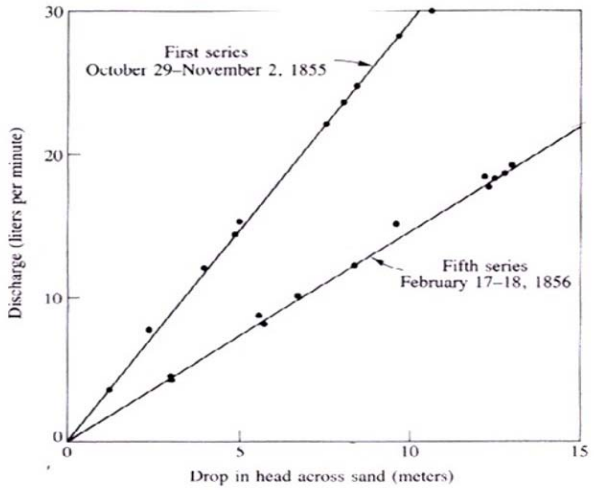
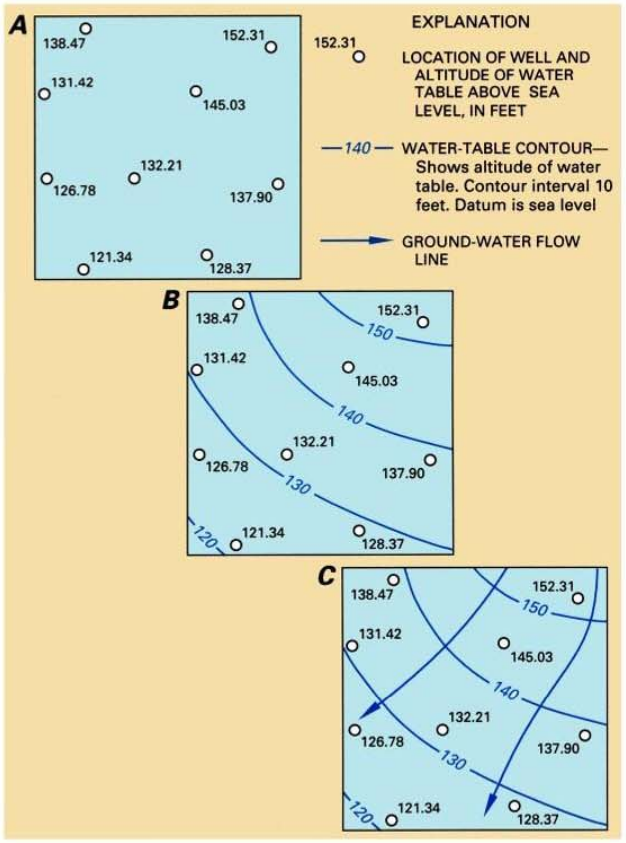
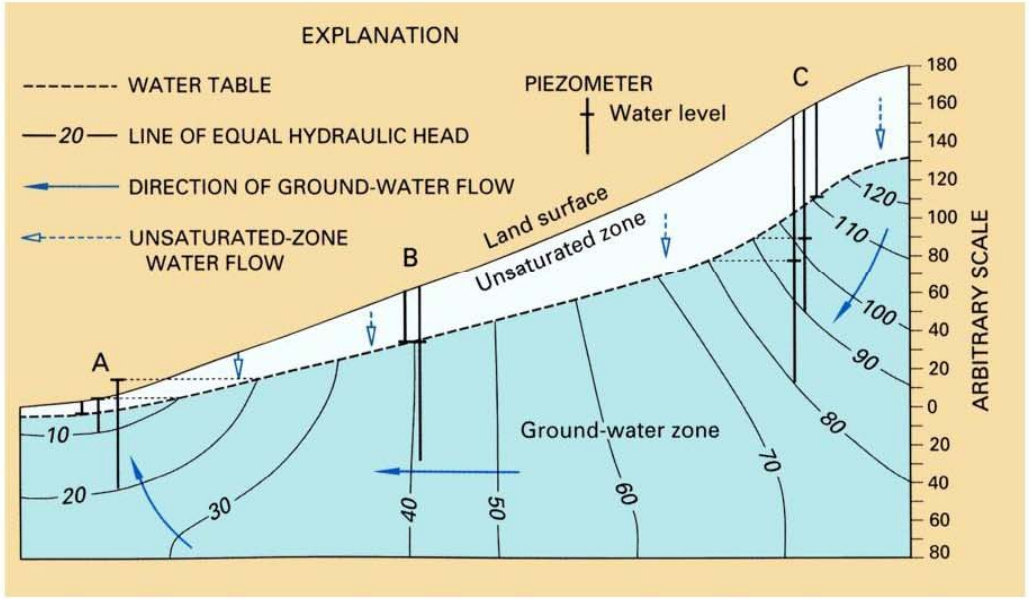


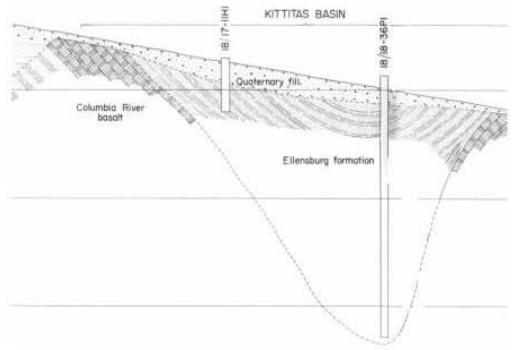
Figure 1.3
Darcy's data showing that discharge is proportional to head drop for two different sands. (From Hubbert, 1969. © 1956, Society of Petroleum Engineers of AIME, published *JPT*, Oct. 1956; *Trans.* AIME, 1956.)

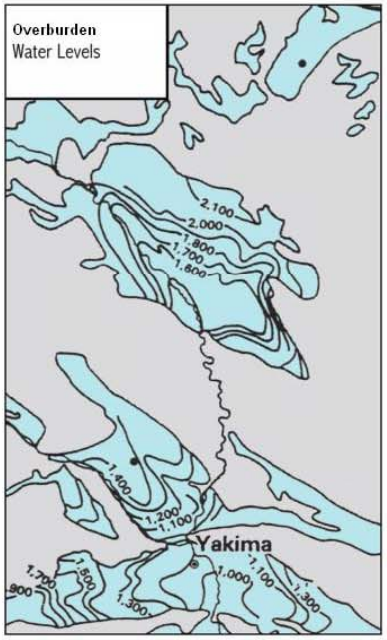
Drop in head divided by length is called hydraulic gradient

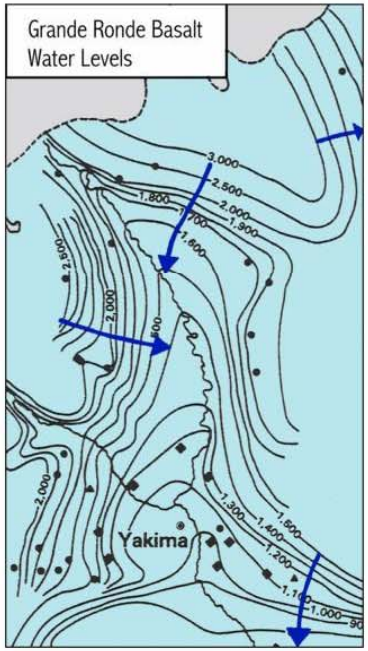
Applying Darcy's Law



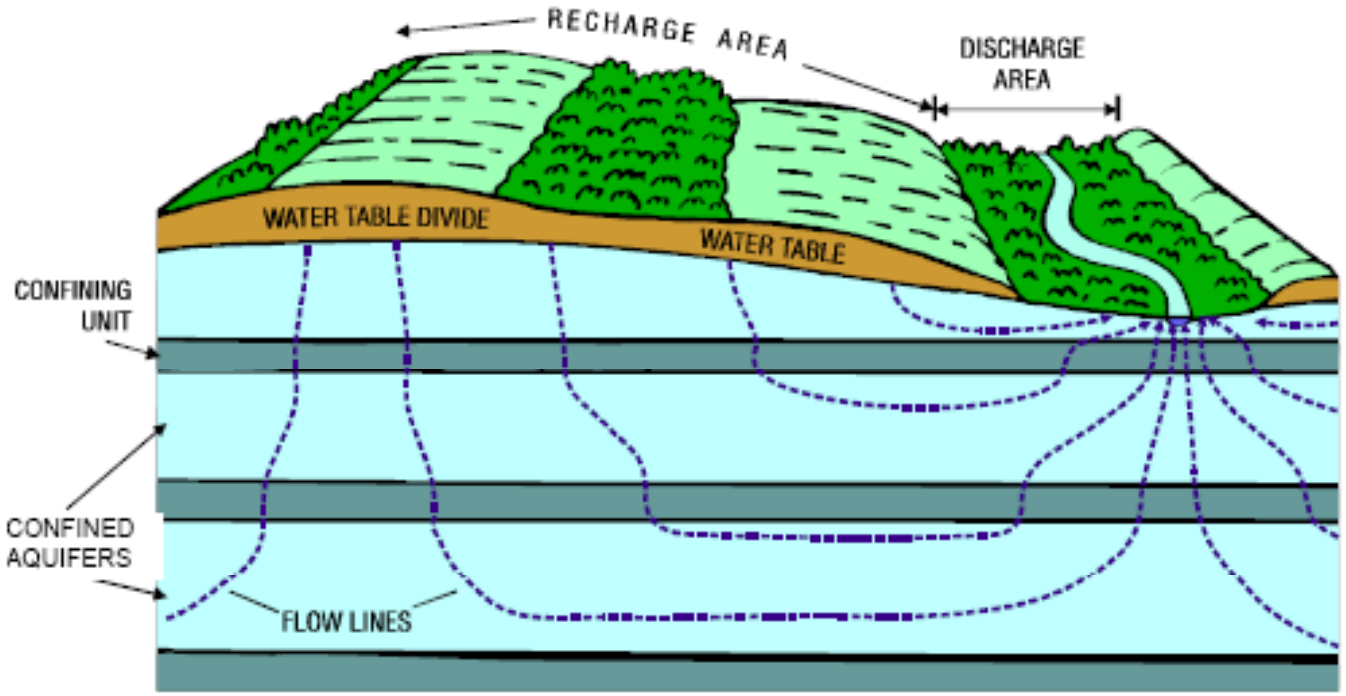








Three-Dimensional Groundwater Flow Through Multiple Hydrogeologic Units from Recharge Area to Discharge Area



- From: Wash. Dep't of Ecology, Report of the Technical Advisory Committee on the Capture of Surface water by wells, draft, 1998, adapted from Heath, 1983

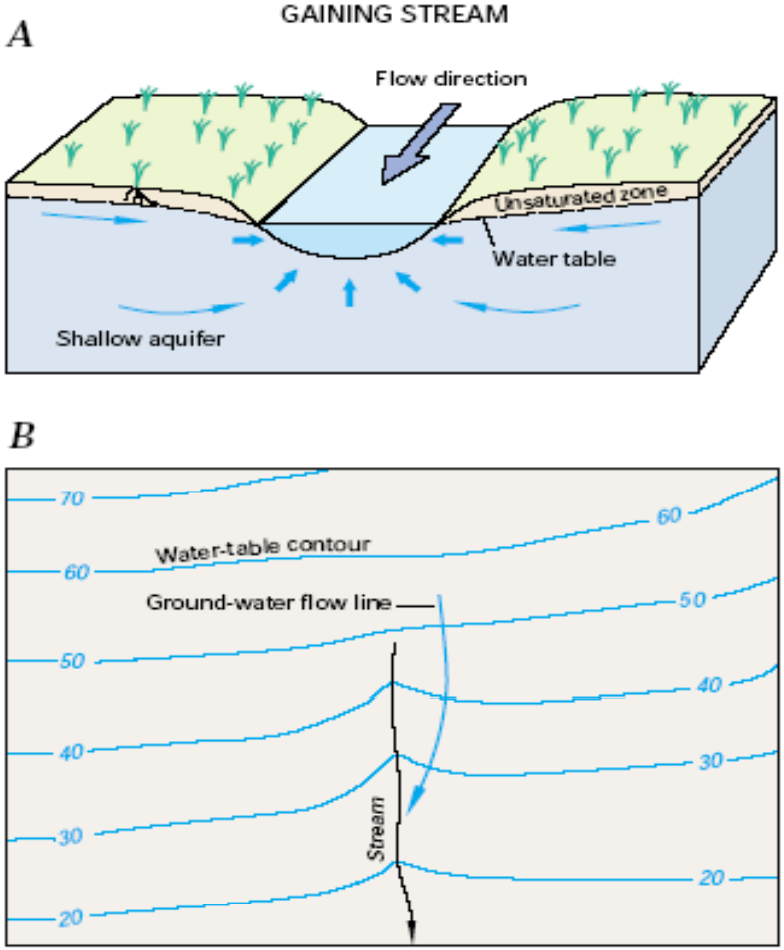


Figure 8. Gaining streams receive water from the ground-water system (A). This can be determined from water-table contour maps because the contour lines point in the upstream direction where they cross the stream (B).

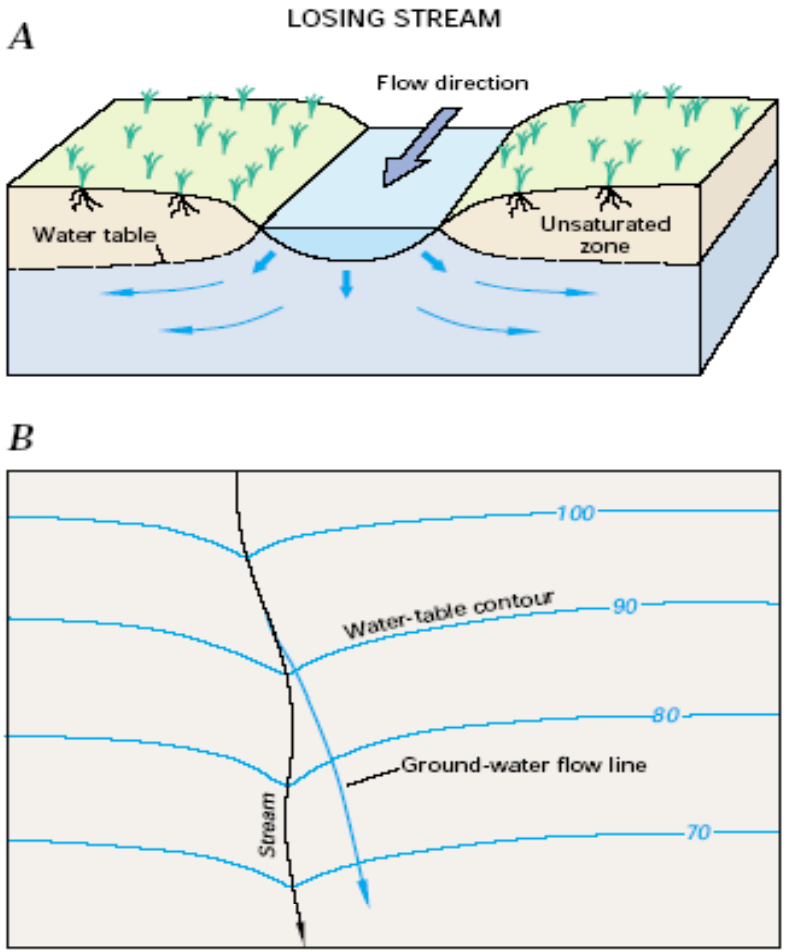
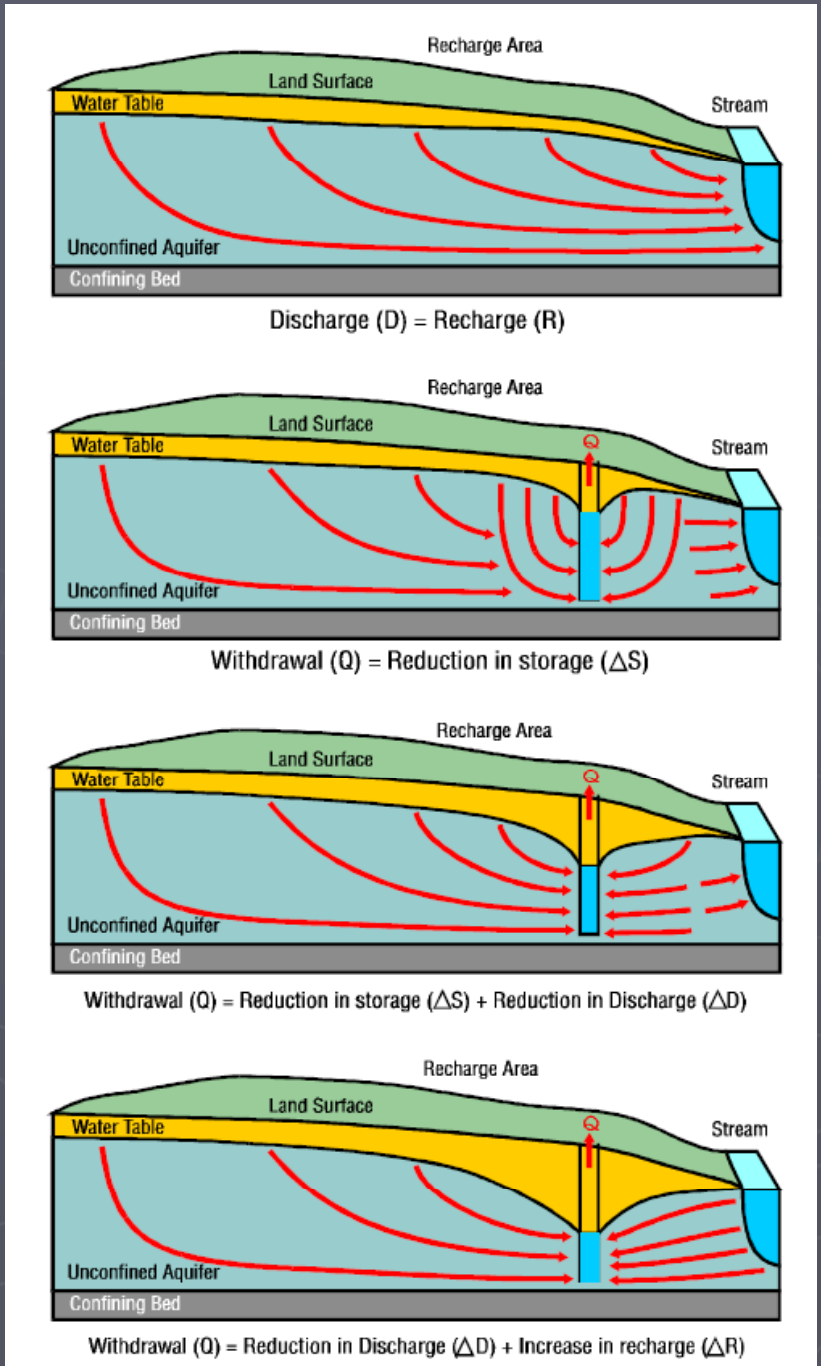


Figure 9. Losing streams lose water to the ground-water system (A). This can be determined from water-table contour maps because the contour lines point in the downstream direction where they cross the stream (B).

Source of Water Derived From Wells

From Heath, 1983

Note: cones of depression Move faster than water

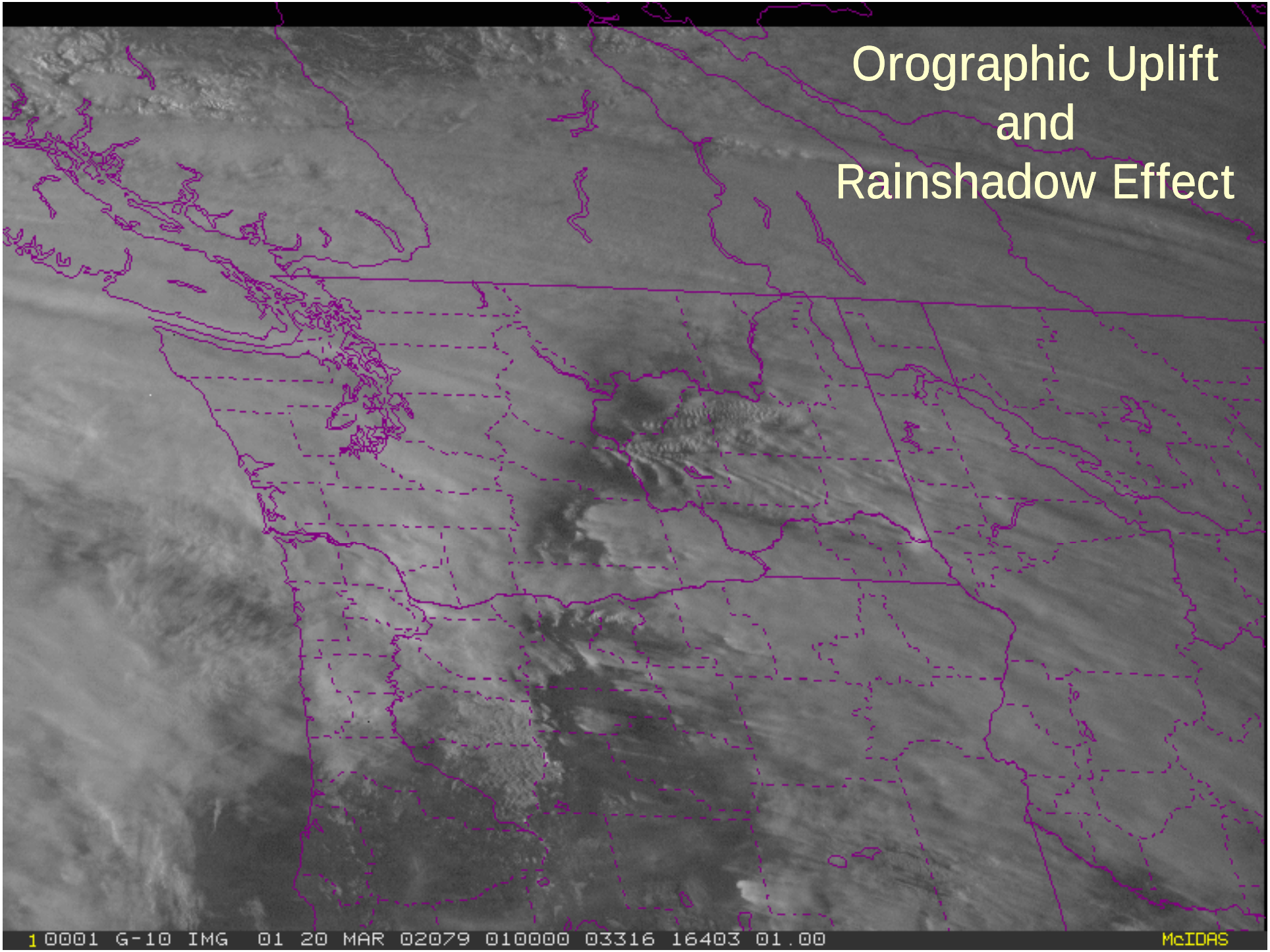


The Laws of Man
Washington Groundwater Law

- 1945 Groundwater Code
- Prior Appropriation
- Recognizes connection to surface water

  - The rights to appropriate the surface waters of the state and the rights acquired by the appropriation and use of surface waters shall not be affected or impaired by any of the provisions of this supplementary chapter and, to the extent that any underground water is part of or tributary to the source of any surface stream or lake, or that the withdrawal of ground water may affect the flow of any spring, water course, lake, or other body of surface water, the right of an appropriator and owner of surface water shall be superior to any subsequent right hereby authorized to be acquired in or to ground water (**RCW 90.44.030)**.

Yakima River Basin


Orographic Uplift
and
Rainshadow Effect
1 0001 G-10 IMG 01 20 MAR 02079 010000 03316 16403 01.00
McIDAS

Precipitation

Precipitation is:

– Plentiful in the mountains (orographic uplift)

– Sparse in the lowlands (rainshadow effect)

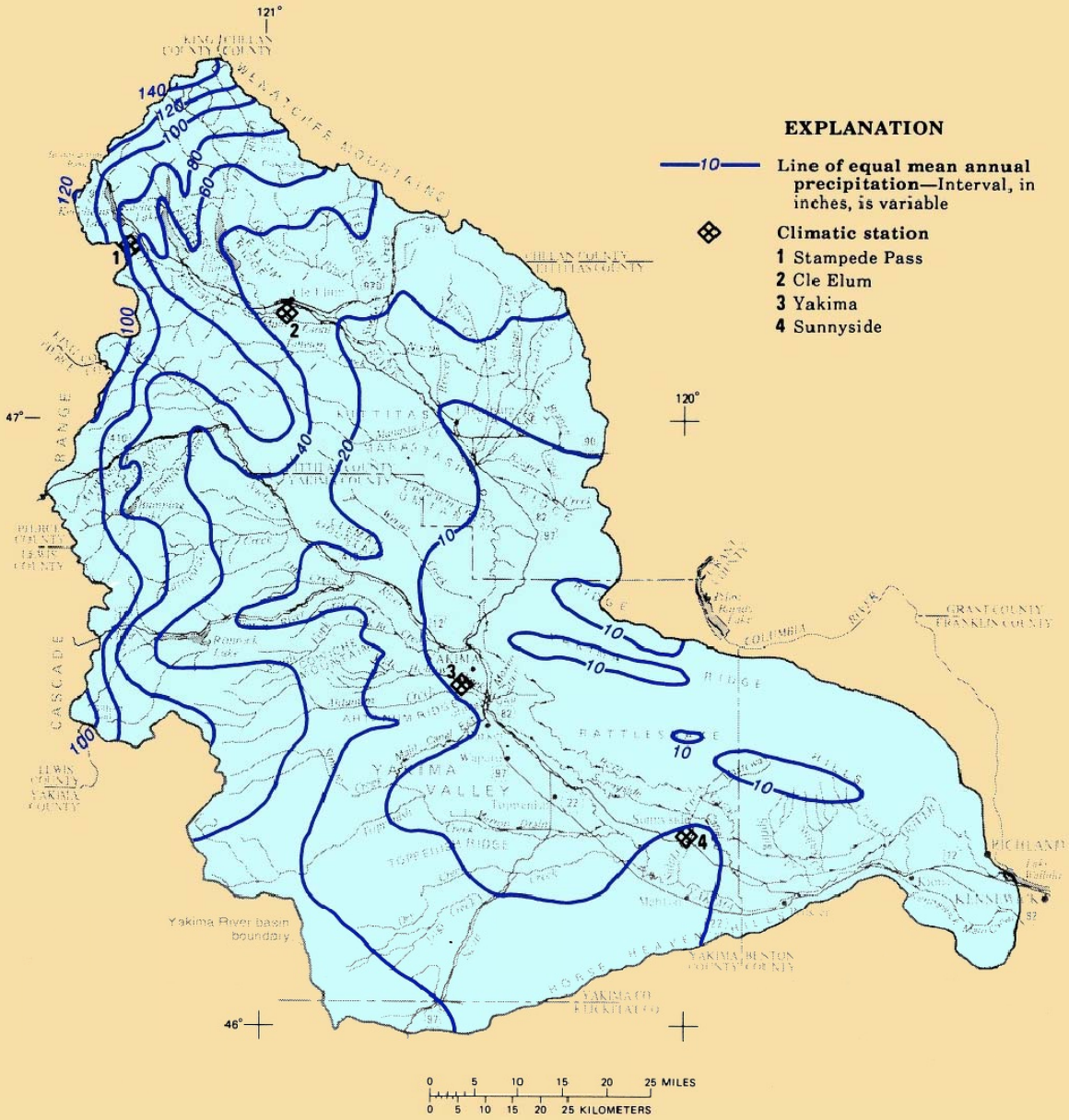
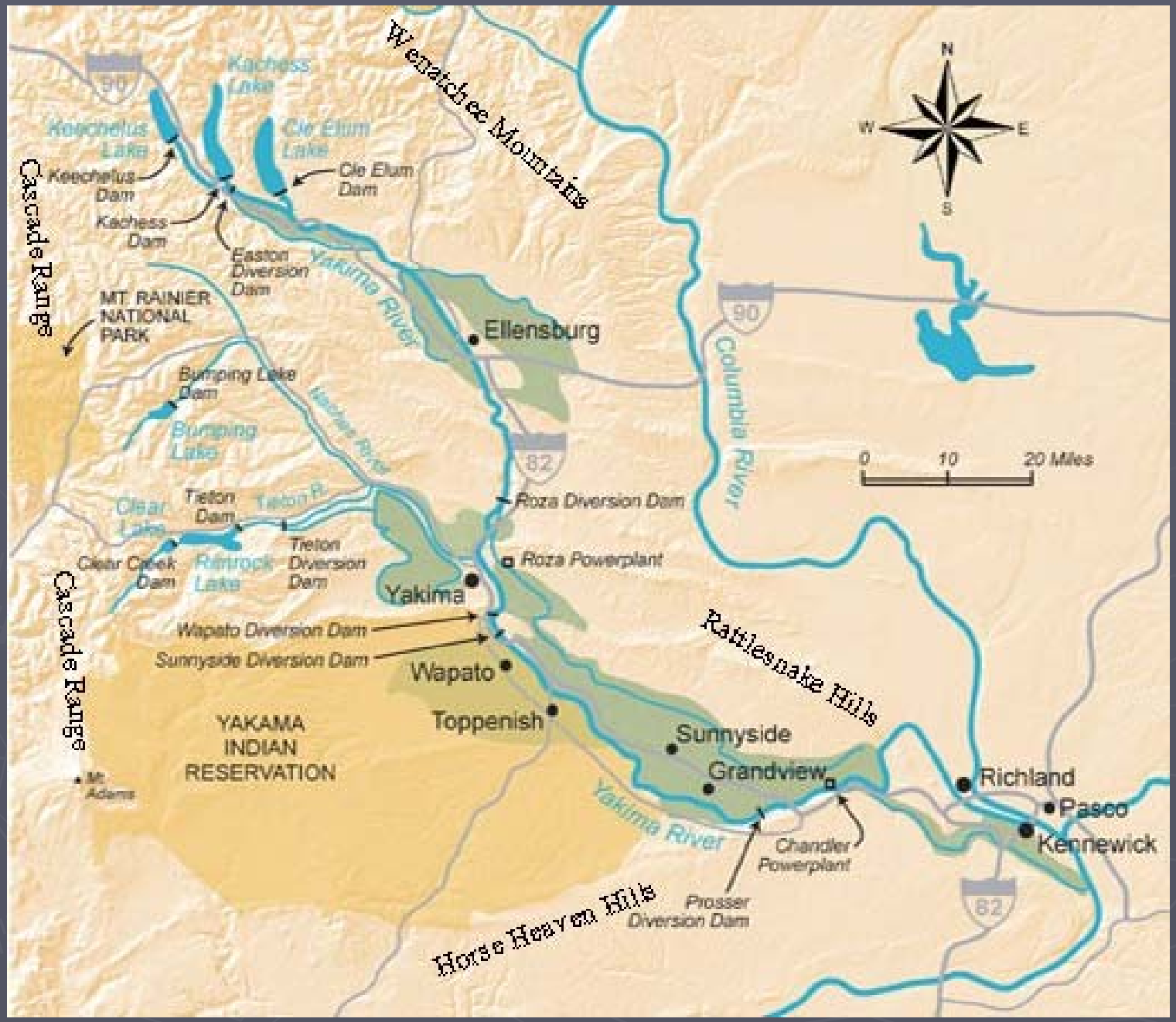


Figure 4.--Mean-annual precipitation in the Yakima River basin, Washington, 1951-80 (National Oceanic and Atmospheric Administration, 1982).

From U.S Geological Survey Open-File Report 91-453


Wenatchee Mountains
Kachess Lake
Keechelus Lake
Cle Elum Lake
Keechelus Dam
Kachess Dam
Cle Elum Dam
Easton Diversion Dam
Yakima River
Cascade Range
MT. RAINIER NATIONAL PARK
Bumping Lake Dam
Bumping Lake
Tieton Dam
Tieton R.
Clear Lake
Clear Creek Dam
Rimrock Lake
Tieton Diversion Dam
Ellensburg
Roza Diversion Dam
Roza Powerplant
Yakima
Wapato Diversion Dam
Sunnyside Diversion Dam
Wapato
Toppenish
YAKAMA INDIAN RESERVATION
Mt. Adams
Cascade Range
Rattlesnake Hills
Sunnyside
Grandview
Yakima River
Chandler Powerplant
Prosser Diversion Dam
Horse Heaven Hills
Richland
Pasco
Kennewick
Columbia River
90
82
N
S
E
W
0
10
20 Miles

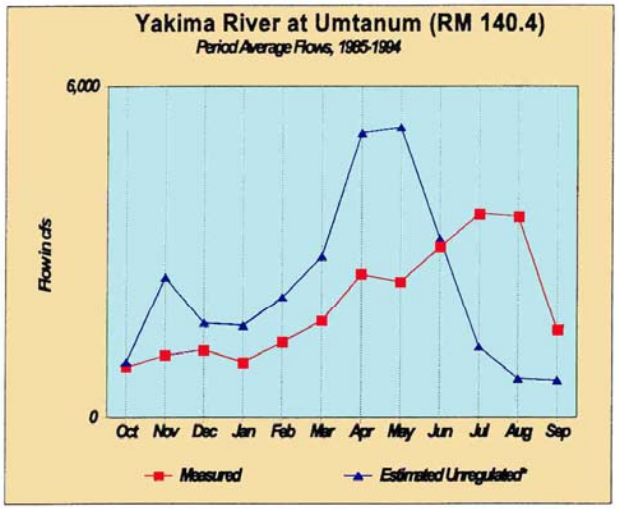


Figure III-1a

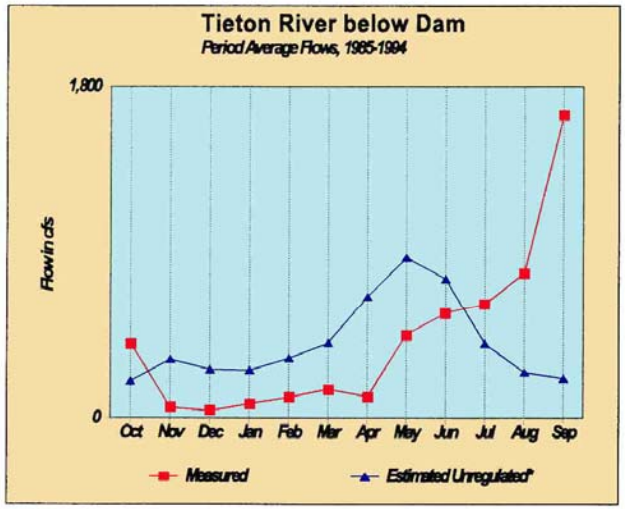


Figure III-1b

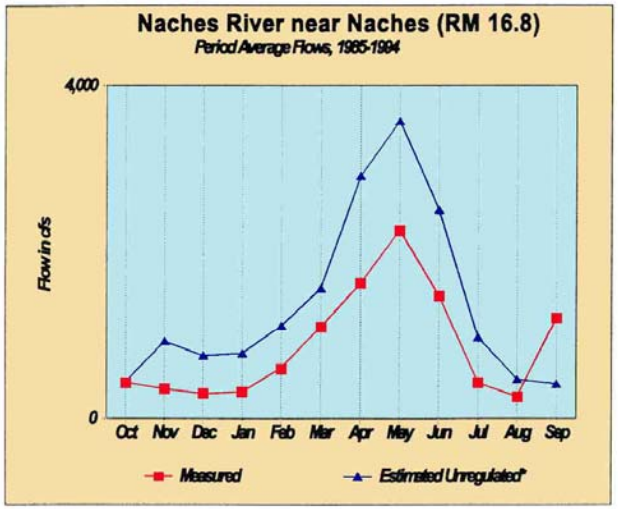


Figure III-1c

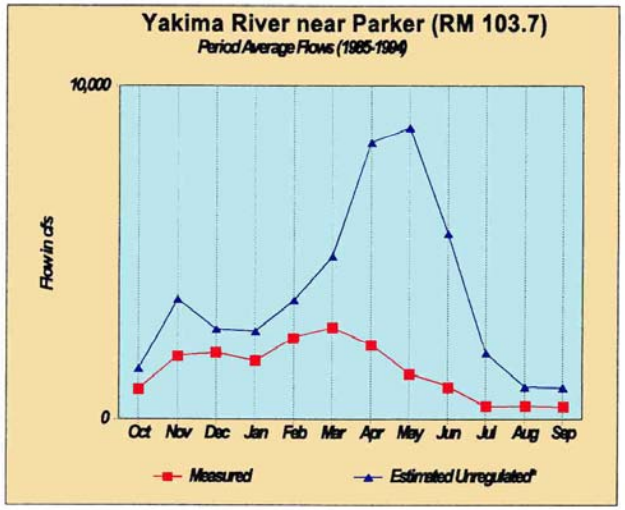


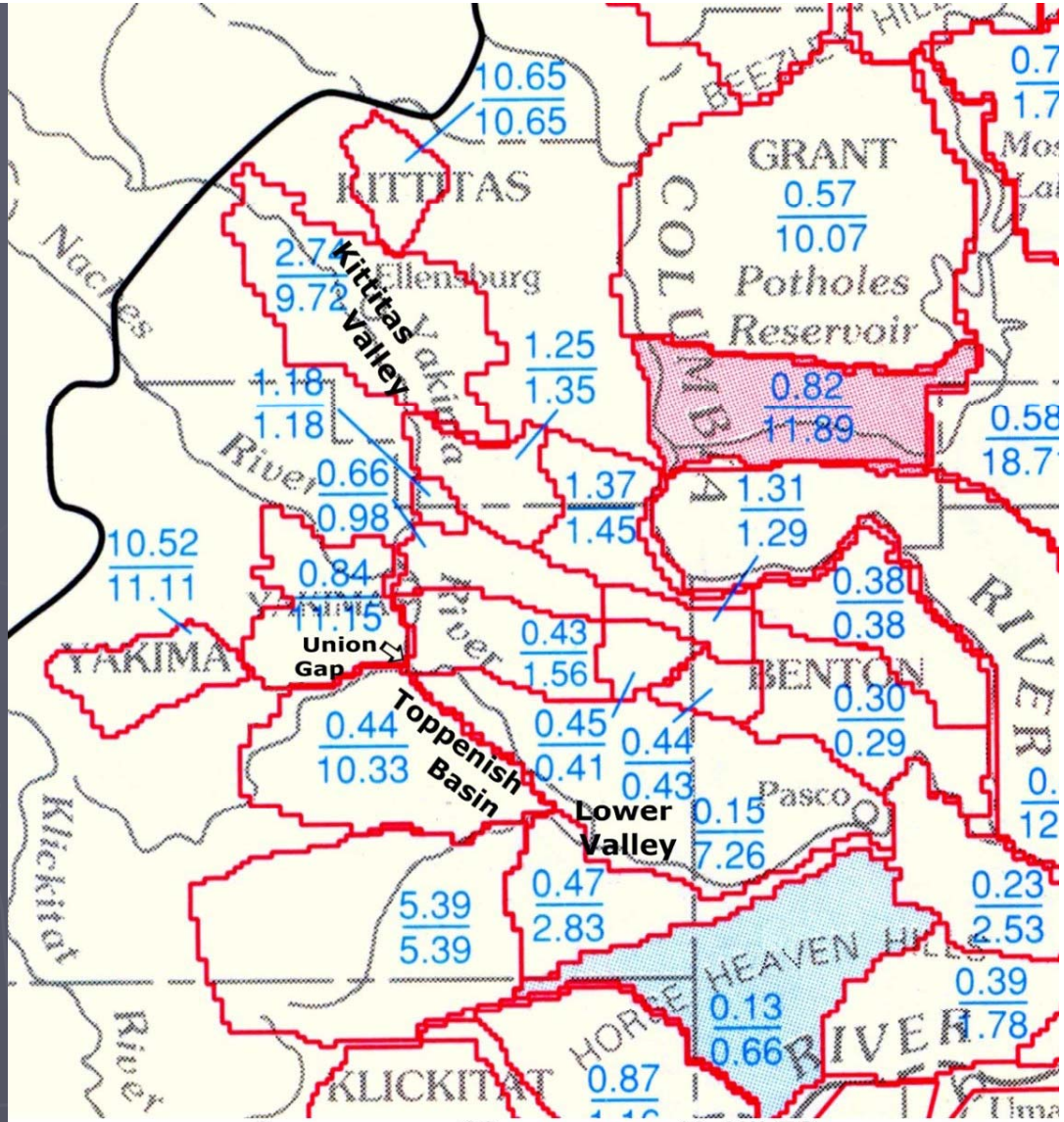
Figure III-1d

Figure III-1.—Conceptual comparison of measured flow and estimated unregulated flow (measured flow corrected for storage, estimated diversions, and estimated return flows).

From YRBWEP Draft Programmatic Environmental Impact Statement

Recharge

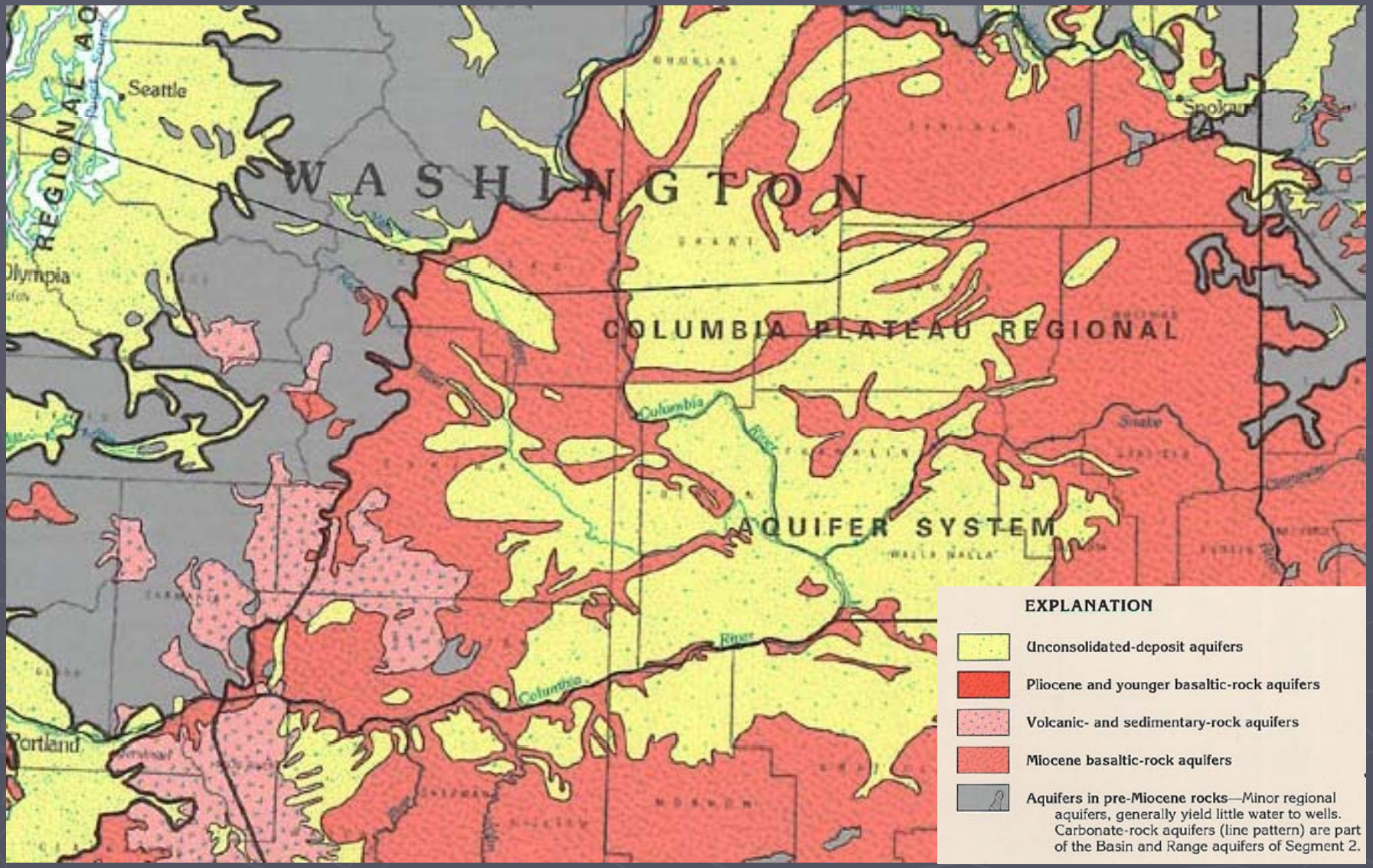
- In the lowlands, most precipitation is consumed by ET
- Irrigation has increased recharge tenfold in the lower valley
- Recharge in this figure was calculated using a deep percolation model



ESTIMATE OF AVERAGE RECHARGE, IN INCHES PER YEAR—Upper number is predevelopment (1850's); lower number is current (1980's)

Adapted from Whiteman et al., (1994)

Columbia Plateau Regional Aquifer System



Columbia Plateau Regional Aquifer System

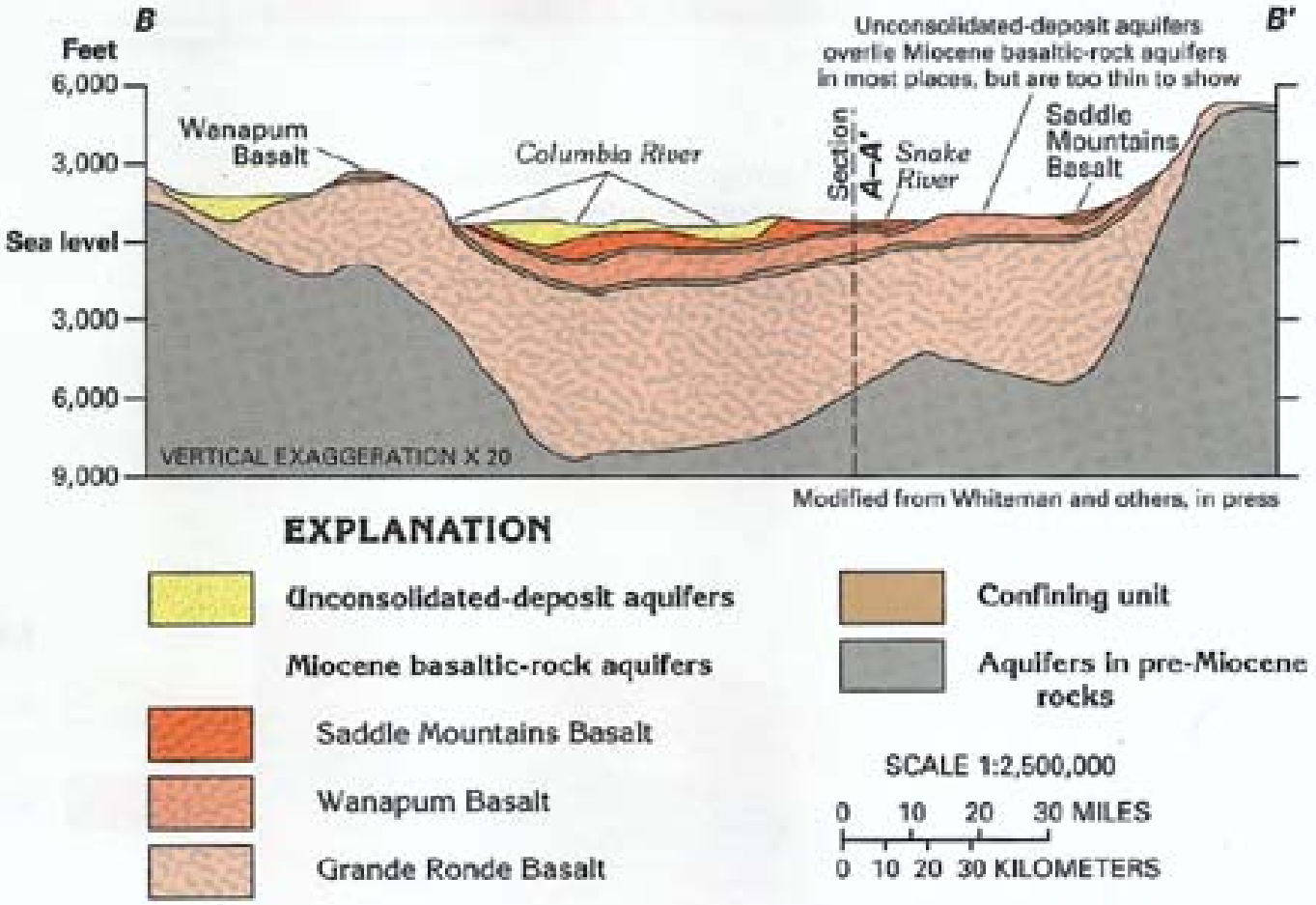


Figure 72. *The Columbia Plateau regional aquifer system consists primarily of three basalt formations separated by confining units. Unconsolidated deposits that overlie the basalt formations also are a part of the aquifer system. The unconsolidated-deposit aquifers are a principal source of water for many wells and locally might be more permeable than the Miocene basaltic-rock aquifers. Collectively, however, the thick Miocene basaltic-rock aquifers generally yield more water than do the unconsolidated-deposit aquifers. Locally, the confining units can yield small volumes of water to wells. The line of the section is shown in figure 70.*

Generalized Flow

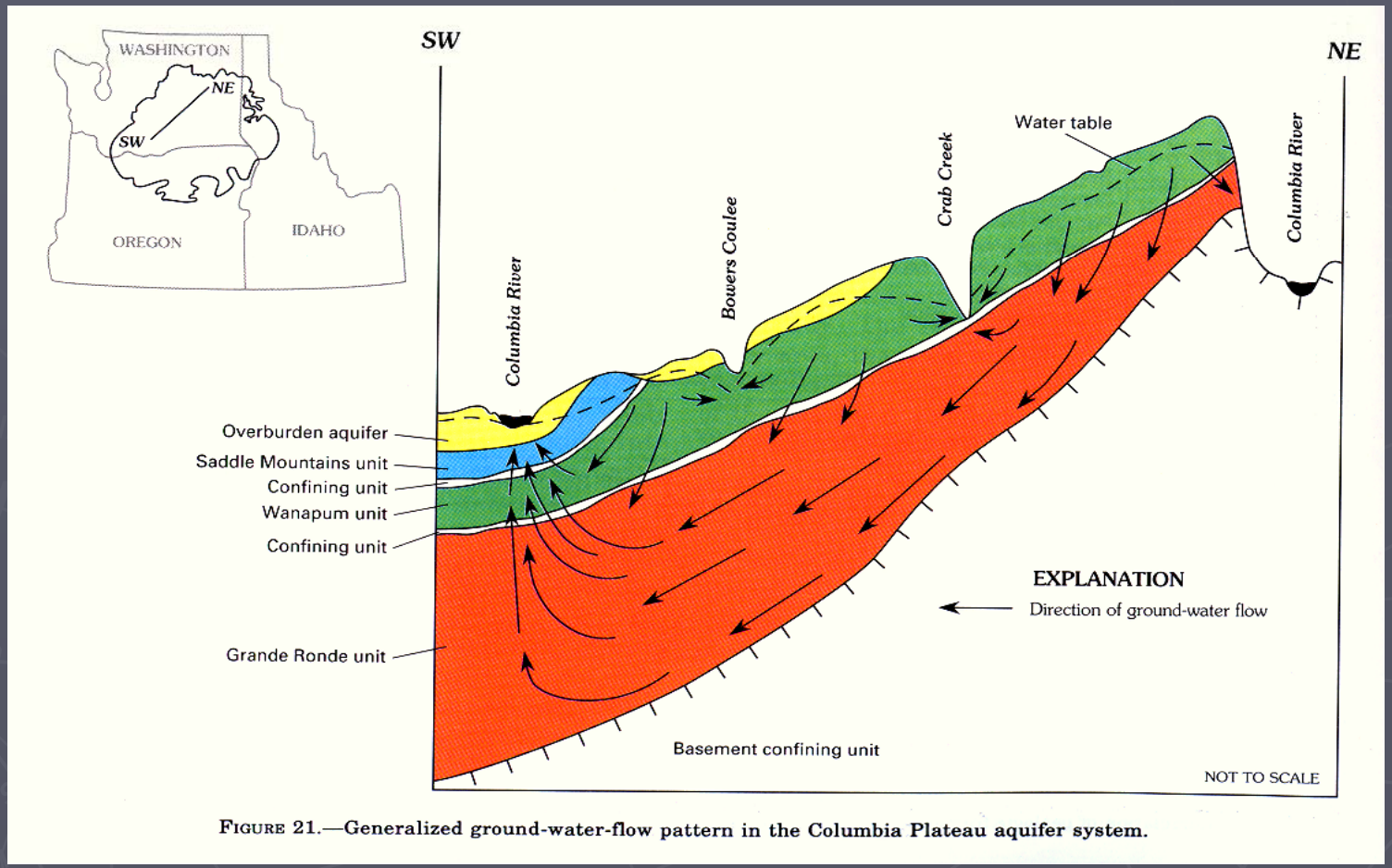
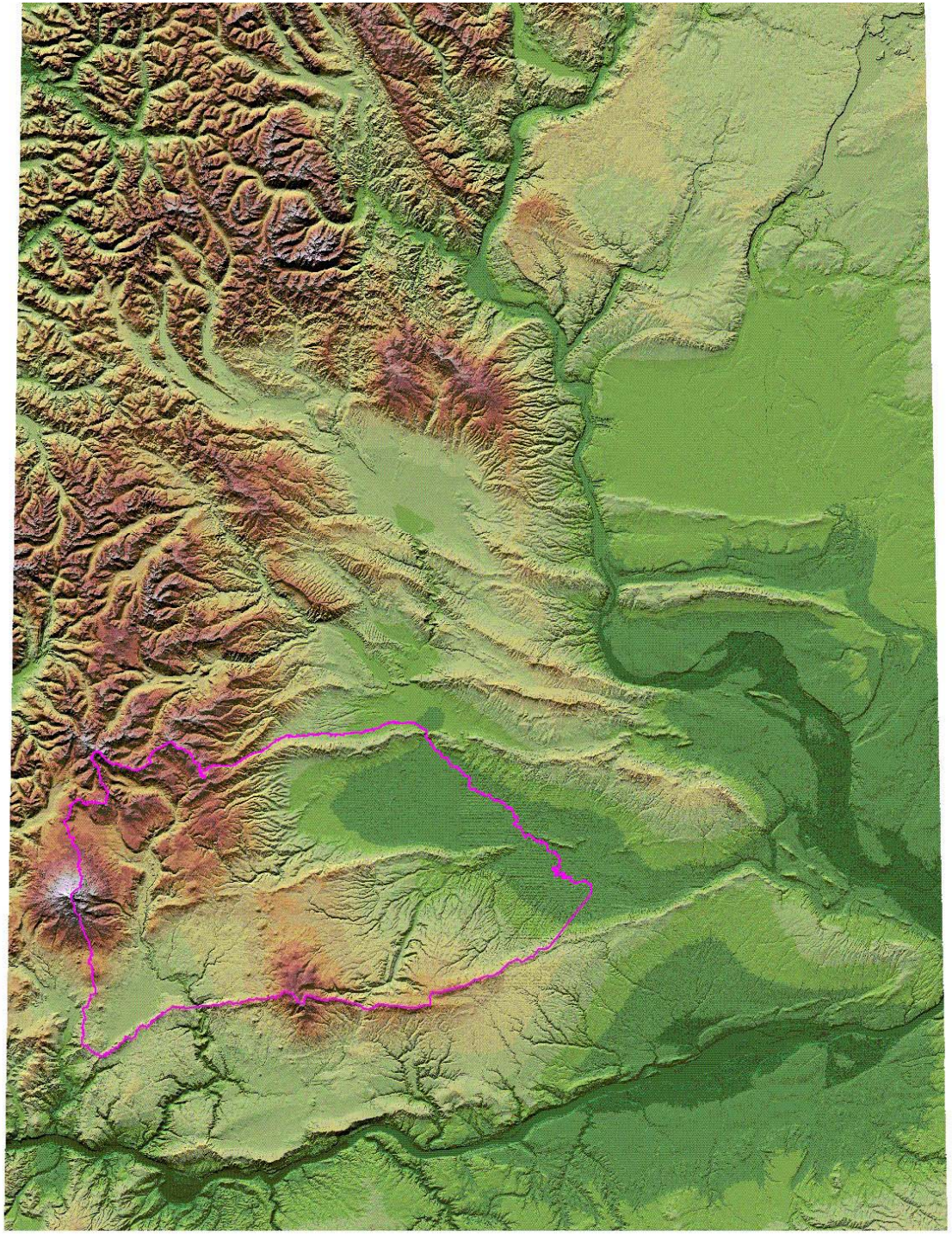


FIGURE 21.—Generalized ground-water-flow pattern in the Columbia Plateau aquifer system.



Synclinal Basin in Yakima Fold and Thrust belt

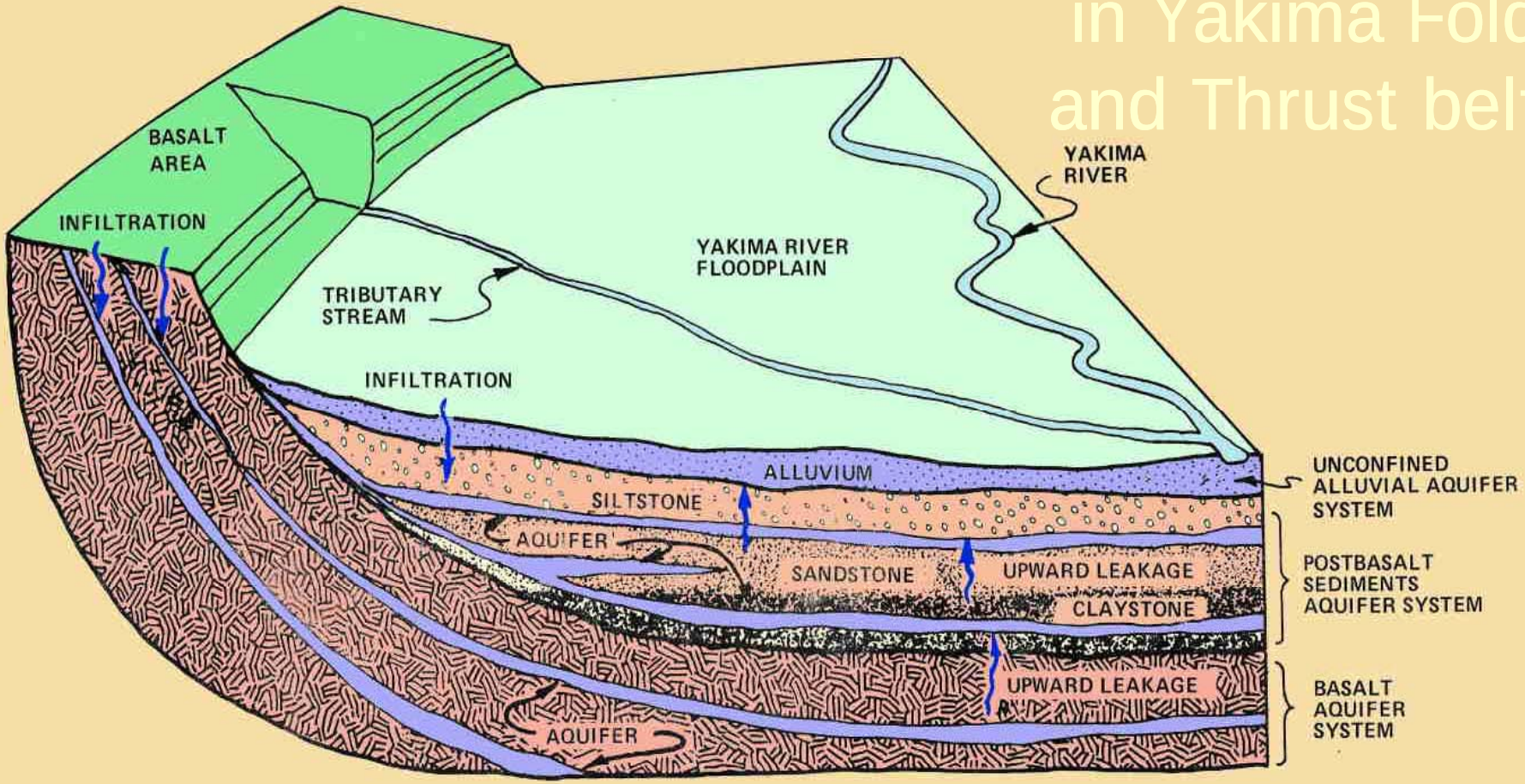
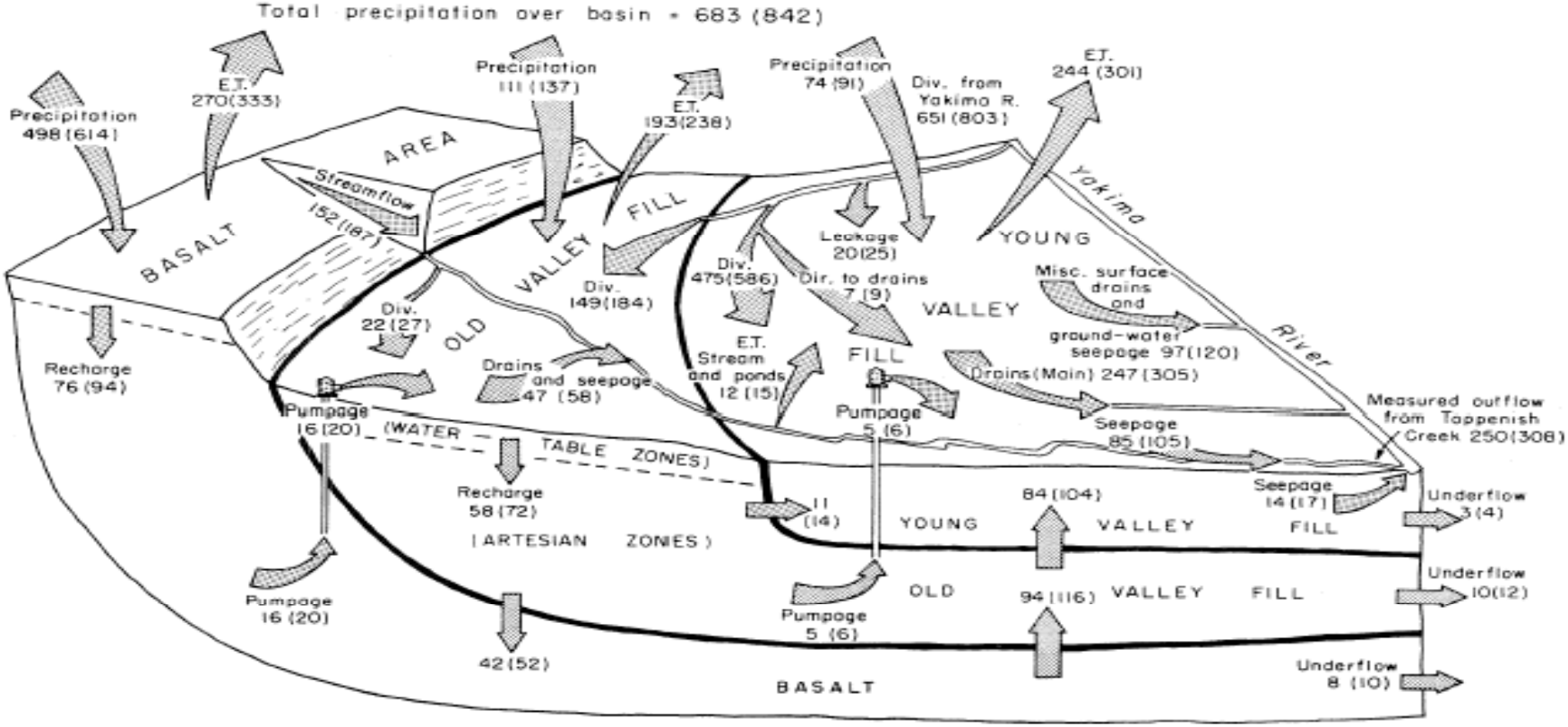


Figure 3. The Three Principal Aquifer Systems in the Yakima River Basin

From U.S. Army Corps of Engineers, 1978,
Yakima Valley Regional Water Management Study

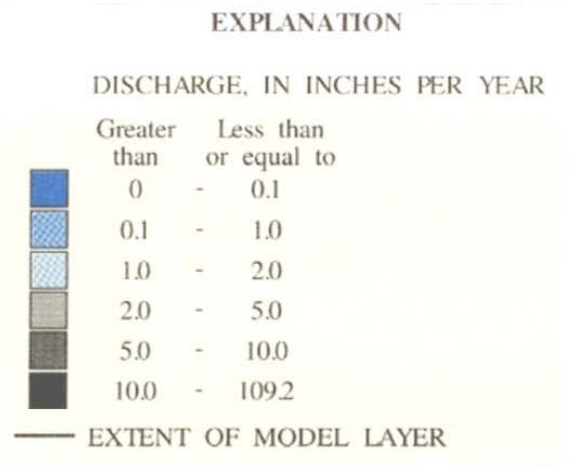
Water Budget Components



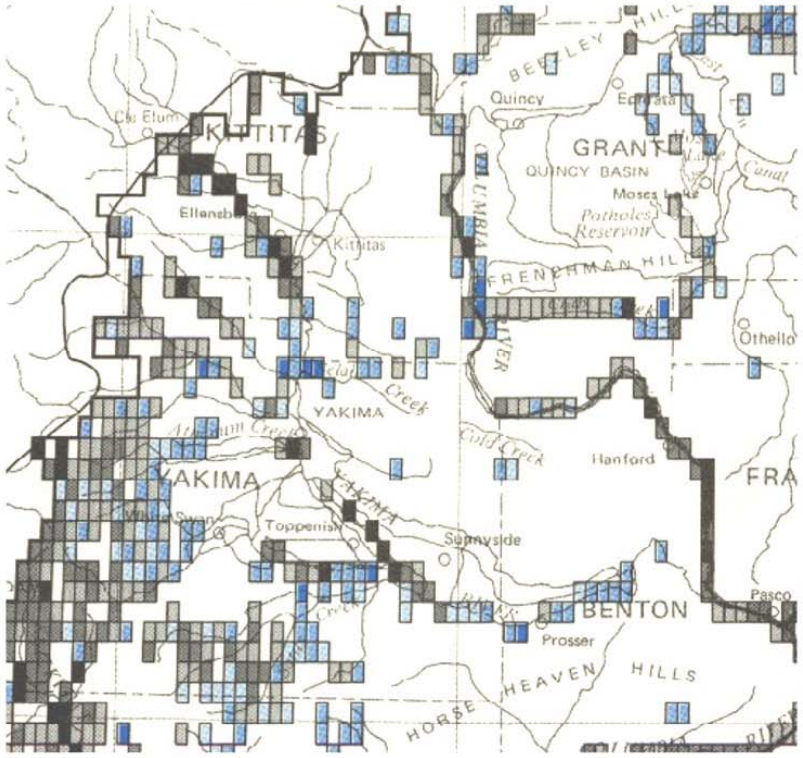
PIGURE 32.--Schematic budget of the hydrologic system in the Toppenish Creek basin. Values are in thousands of acre-feet per year. Values in parentheses are in millions of cubic metres per year.

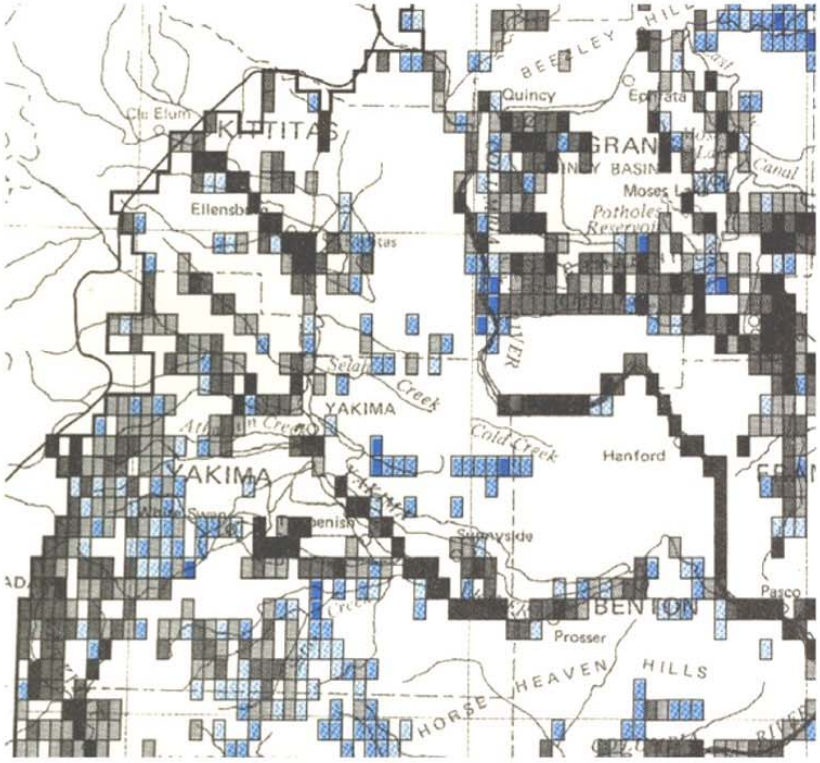
Discharge

More recharge
means more discharge



Model-calculated distribution of groundwater discharge from the aquifer system for predevelopment (1850's, left) and time-averaged conditions. (adapted from U.S. Geological Survey Water-Resources Investigations Report 91-4187).





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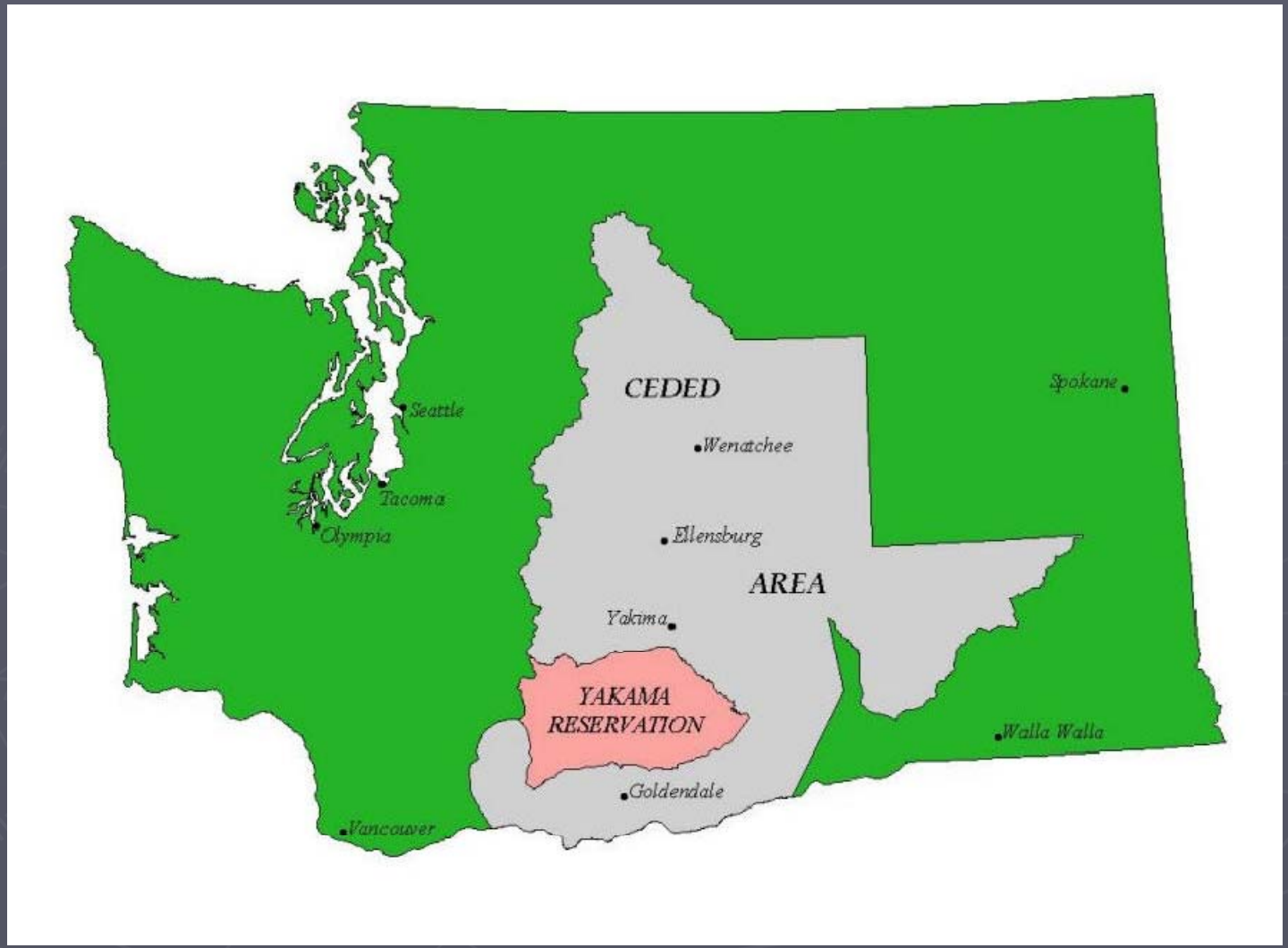
Yakama Nation aboriginal territories



Water Management in the Yakima River Basin

- 3-2-1
- Seniors (pre-1905)
- Juniors aka proratables (May 10, 1905)
- YN
  - Time Immemorial - Quackenbush
  - 1855
  - 1905 Proratable
- 1945 Consent Decree
  - TWSA Storage Control
- Acquavella – no groundwater
- YRBWEP – Target flows, BCP

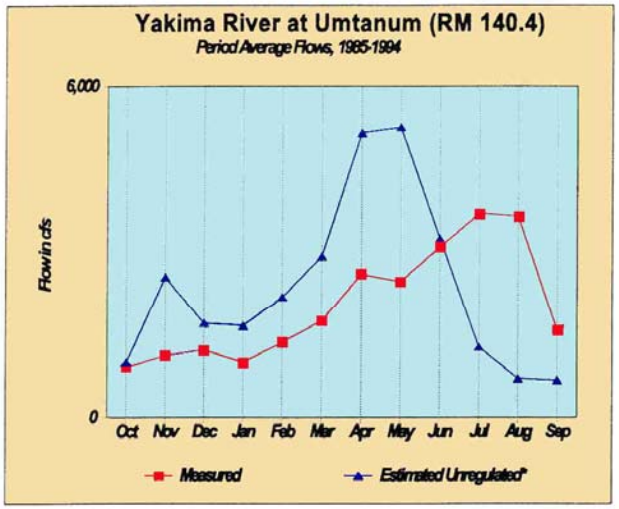


Figure III-1a

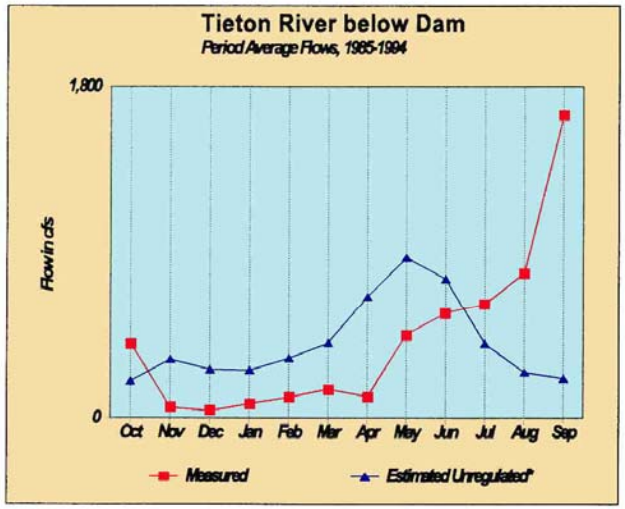


Figure III-1b

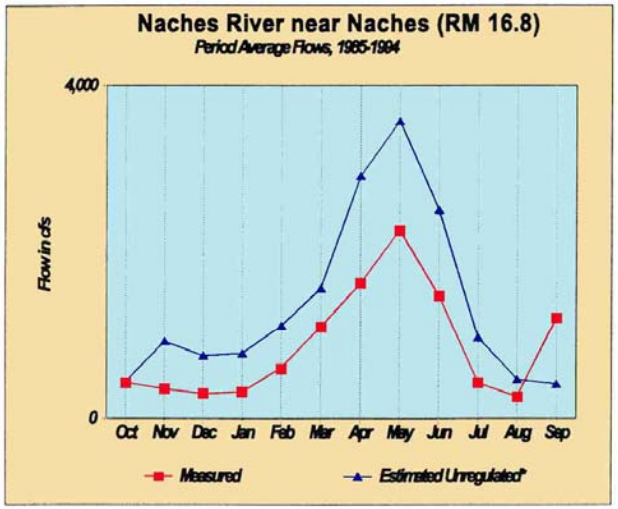


Figure III-1c

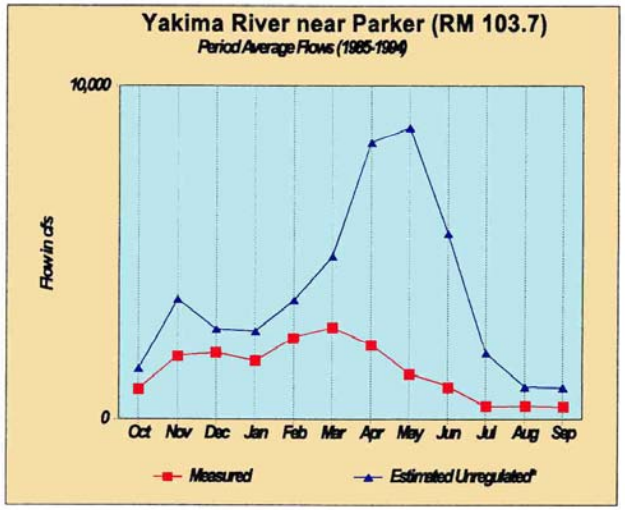


Figure III-1d

Figure III-1.—Conceptual comparison of measured flow and estimated unregulated flow (measured flow corrected for storage, estimated diversions, and estimated return flows).

From YRBWEP Draft Programmatic Environmental Impact Statement

Bad Data at Black Rock

- Aquifers in decline
- Demand on the rise
- It was a dark and stormy night (the BR study)
- A public meeting and a modest proposal
  - Go west (of the Bird Creek Fault), young appropriator
- BR study exclusively dealt with mining

Mr. Ring Reviews the Literature

- Inflow = outflow....
- Darcy's Law
- Groundwater is tributary to Yakima River
- Pumping will diminish flow, maybe soon

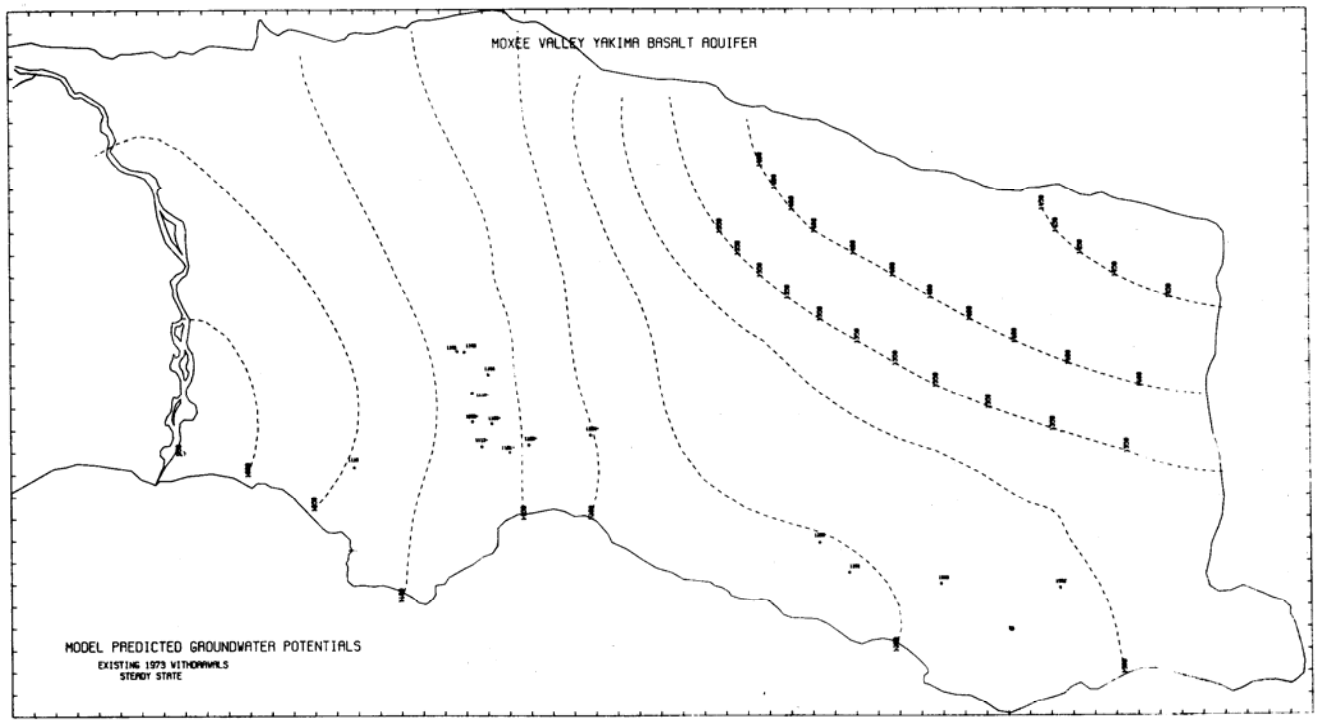
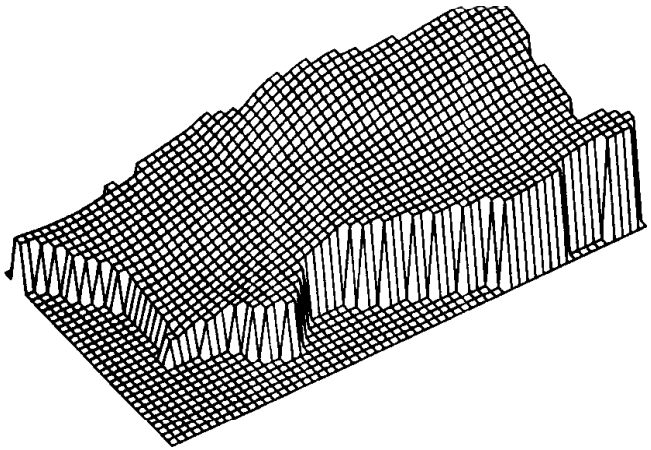
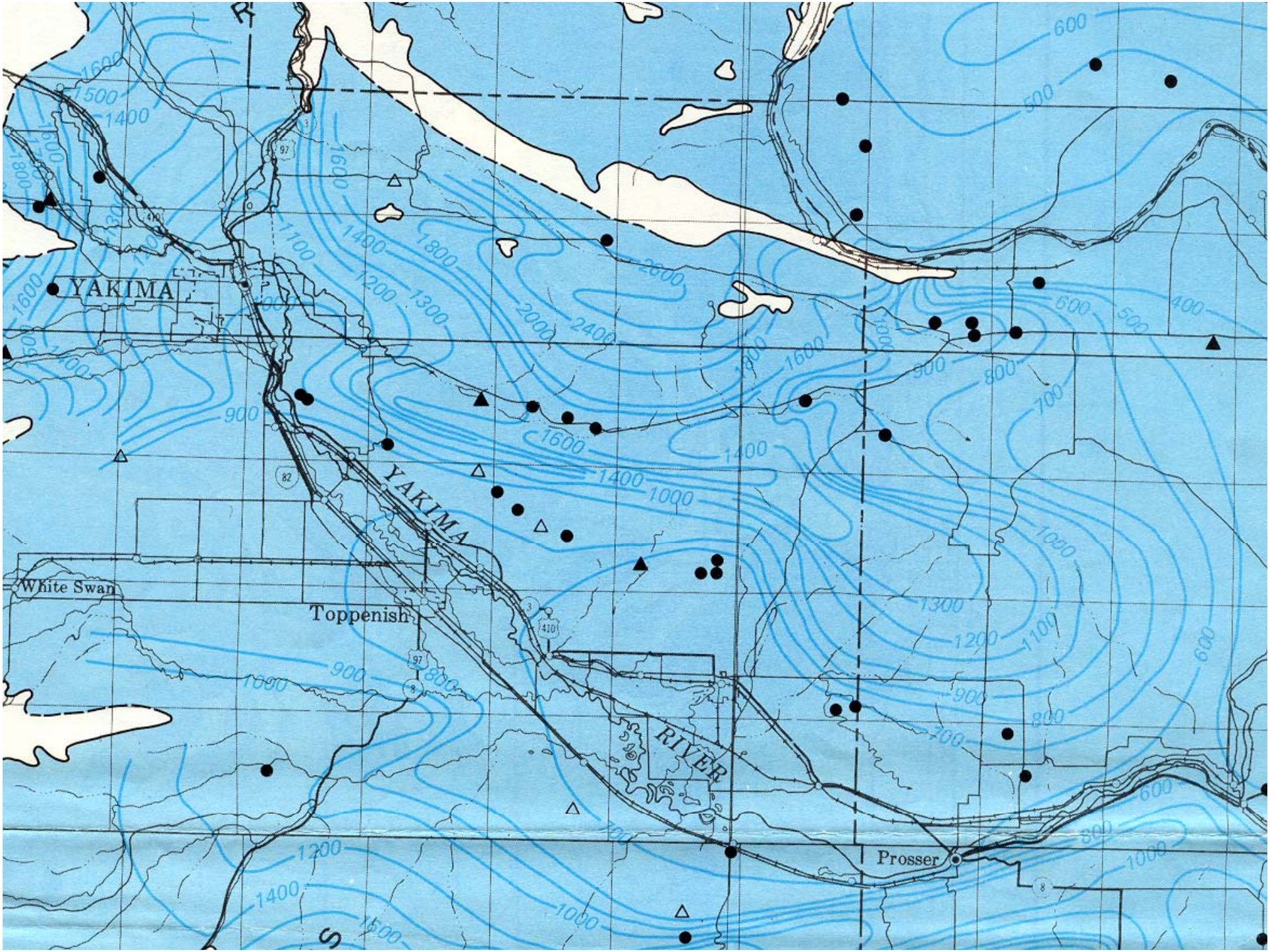
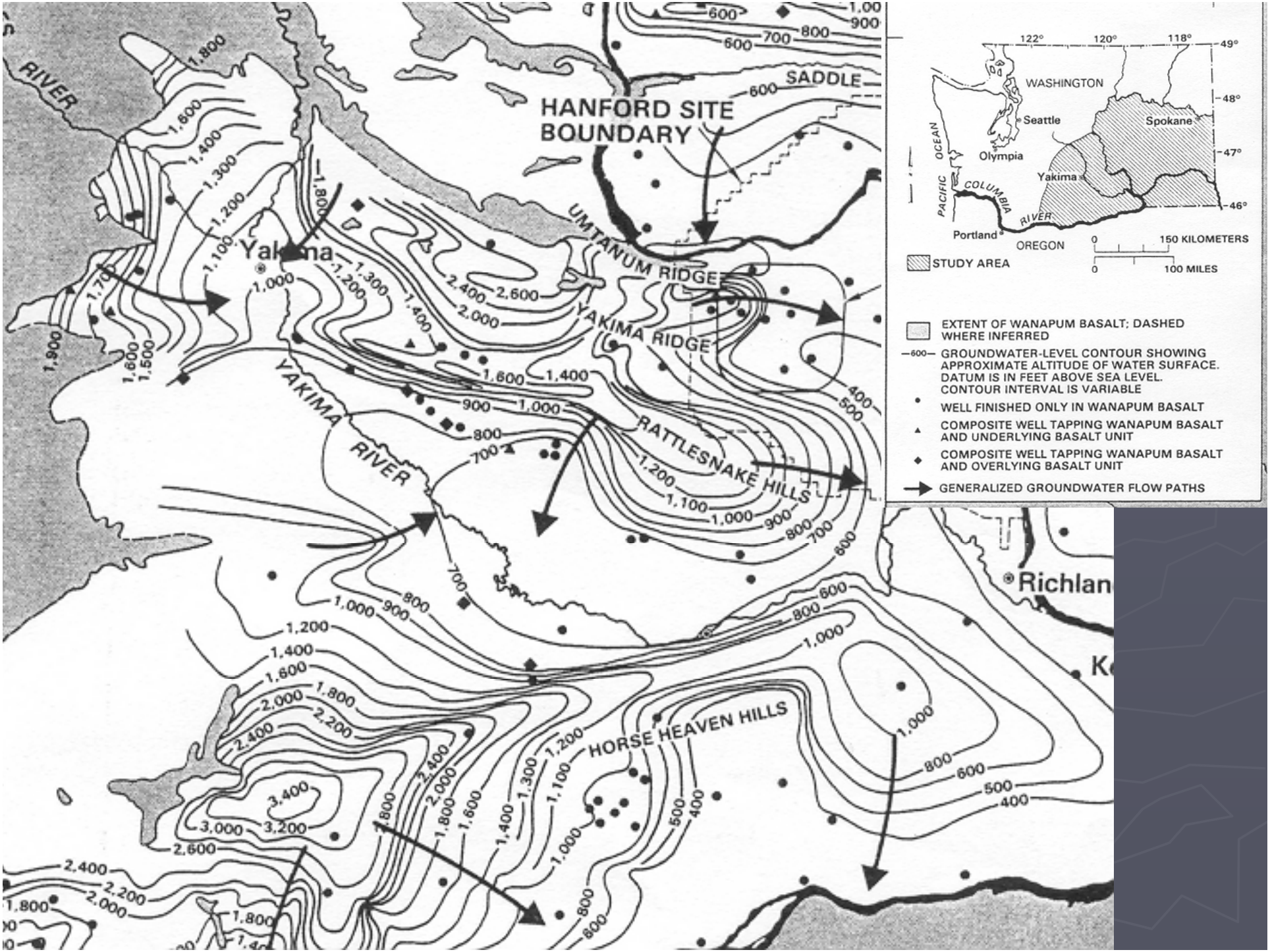


FIGURE 10c. Model Predicted Potentials Versus Observed 1973 Values for the Yakima Basalt Aquifer in the Moxee Valley



Moxee Valley Isometric View of 1973 Yakima Basalt Potentials


YAKIMA
YAKIMA
White Swan
Toppenish
RIVER
Prosser


HANFORD SITE BOUNDARY
SADDLE
UMTANUM RIDGE
YAKIMA RIDGE
RATTLESNAKE HILLS
HORSE HEAVEN HILLS
YAKIMA RIVER
RIVER
Yakima
Richlan
122°
120°
118°
49°
48°
47°
46°
WASHINGTON
Seattle
Spokane
Olympia
Yakima
PACIFIC OCEAN
COLUMBIA RIVER
Portland
OREGON
0 150 KILOMETERS
0 100 MILES
STUDY AREA
EXTENT OF WANAPUM BASALT; DASHED WHERE INFERRED
—600— GROUNDWATER-LEVEL CONTOUR SHOWING APPROXIMATE ALTITUDE OF WATER SURFACE. DATUM IS IN FEET ABOVE SEA LEVEL. CONTOUR INTERVAL IS VARIABLE
WELL FINISHED ONLY IN WANAPUM BASALT
COMPOSITE WELL TAPPING WANAPUM BASALT AND UNDERLYING BASALT UNIT
COMPOSITE WELL TAPPING WANAPUM BASALT AND OVERLYING BASALT UNIT
GENERALIZED GROUNDWATER FLOW PATHS

Can We Talk?

YN and Ecology staffs meet in Toppenish

- I guess you want to talk about water
- Yeah, you're right, so what
- Hypothetical hydrologic cycle
- Years, decades, centuries, millenia: what's a few orbits among friends
- How much, I don't know, a lot
- Agreement to disagree, disclose
- The Literature Review in 37tuplicate

The Decisions
Inferring the policy

- Direct vs. Indirect Hydraulic Continuity: a difference without a distinction
- Only permit deep wells except for some shallow ones
- No mining = no impact to surface water
- Supplemental ok, primary not ok, except where it is
- Hydrocooling and frost protection not in public interest
- Most recharge from irrigation water
- BR study dismisses capture concern

A timely 4-year challenge to timeliness

- YN appeals
- Timeliness challenged...
- Statewide cases
- Hubbard
- Chain of command changed from permit writer to Governor
- 25 out of 43 spring back to life in 1997

Enter the 800 Pound Gorilla Reclamation Rings In

- Hey, Buddy, that's my WSRF
- Affidavit
  - If continuity exists, and it appears to, then it's our water and you're impairing our contractor's rights and interfering with our duties to protect and enhance the river
- Amicus (denied)

Depositions & Summary Judgments

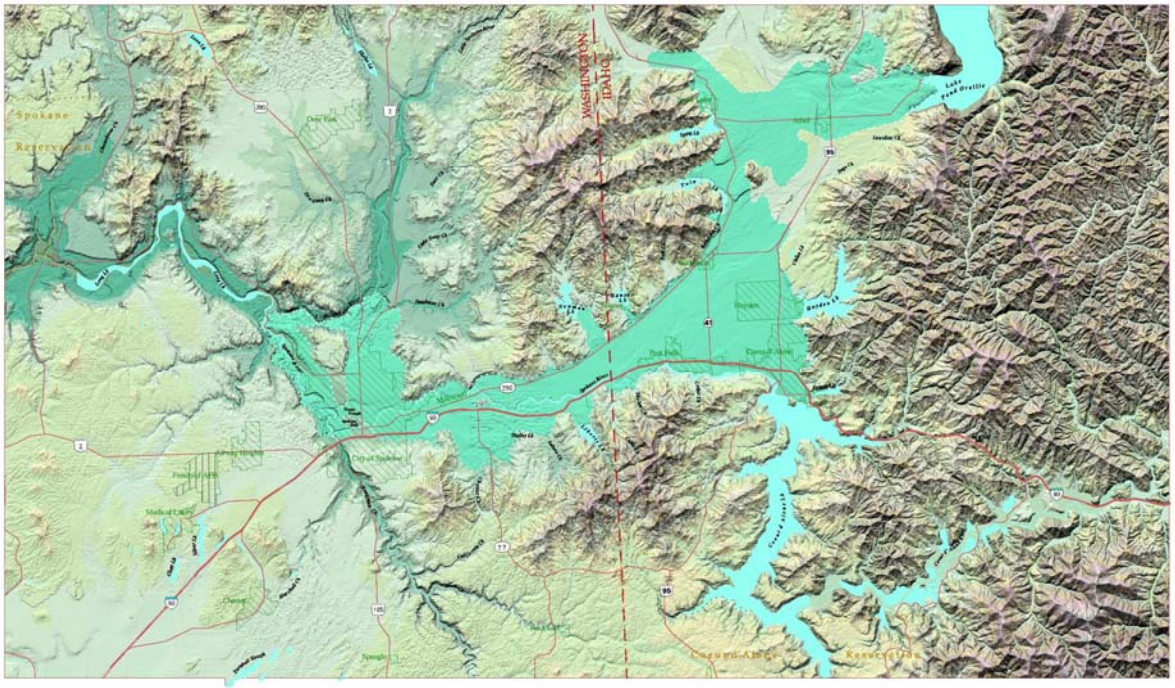
- You said it
- Pumping from wells will capture river flow over time
- Gw is cooler and cleaner; pumping will make river hotter and dirtier
- Every drop is important
- Denied

The 3 Sovereigns Agree to Agree

- Ecology letter to permittees
  - We've learned a thing or two
  - If we had it to do over again...
  - We won't defend the permits
- Settlements
  - Permittees to pay replacement cost for water into BOR water acquisition fund
- The MOA

The MOA

- The 3 govs will contract USGS to develop a model to simulate effects of existing and proposed groundwater pumping
- Model will serve as technical platform for future decisions
- Study team (hg's from 3 govs) will draft scope and oversee project
- Ecology will not issue permits during study



The Spokane Valley - Rathdrum Prairie Aquifer

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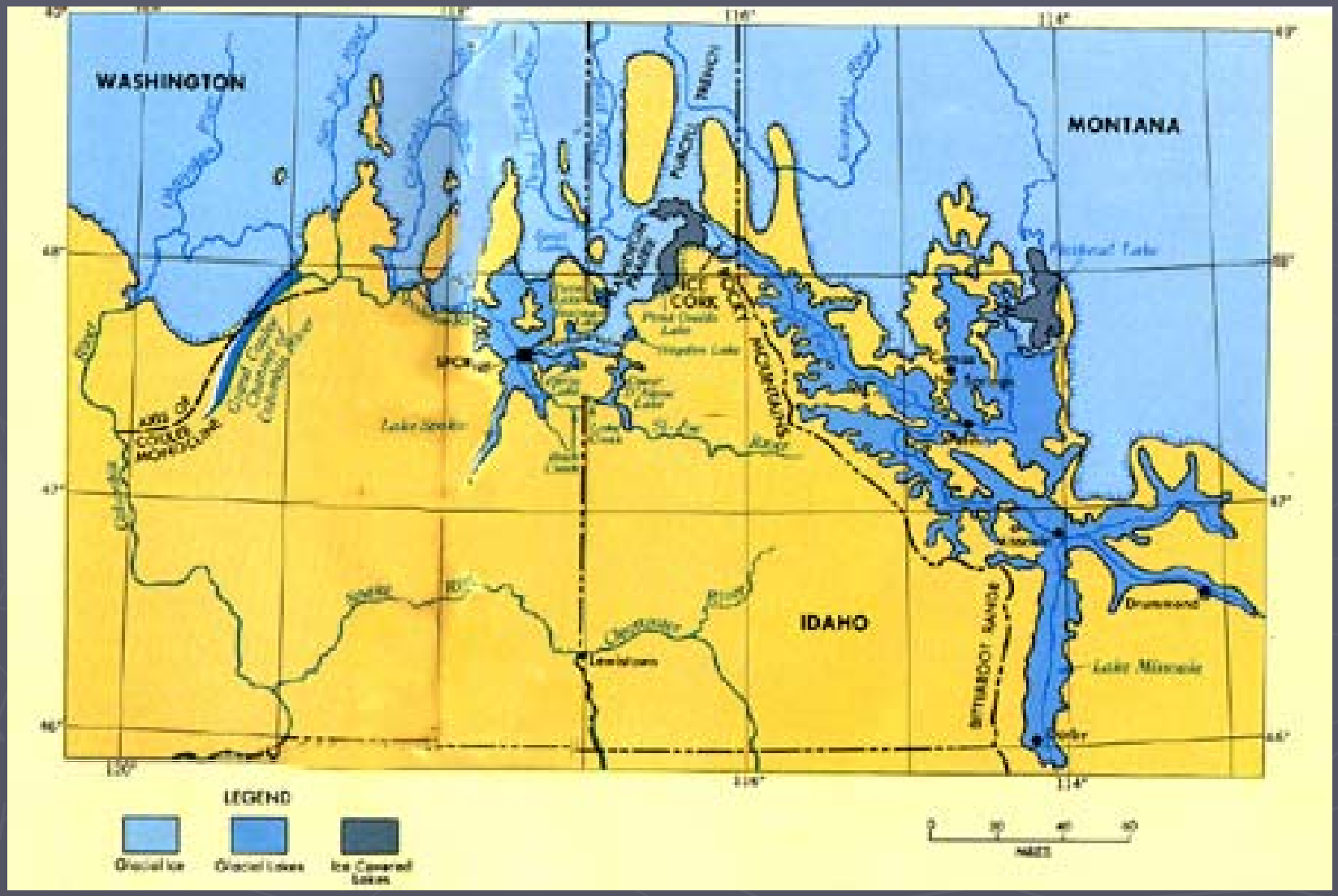
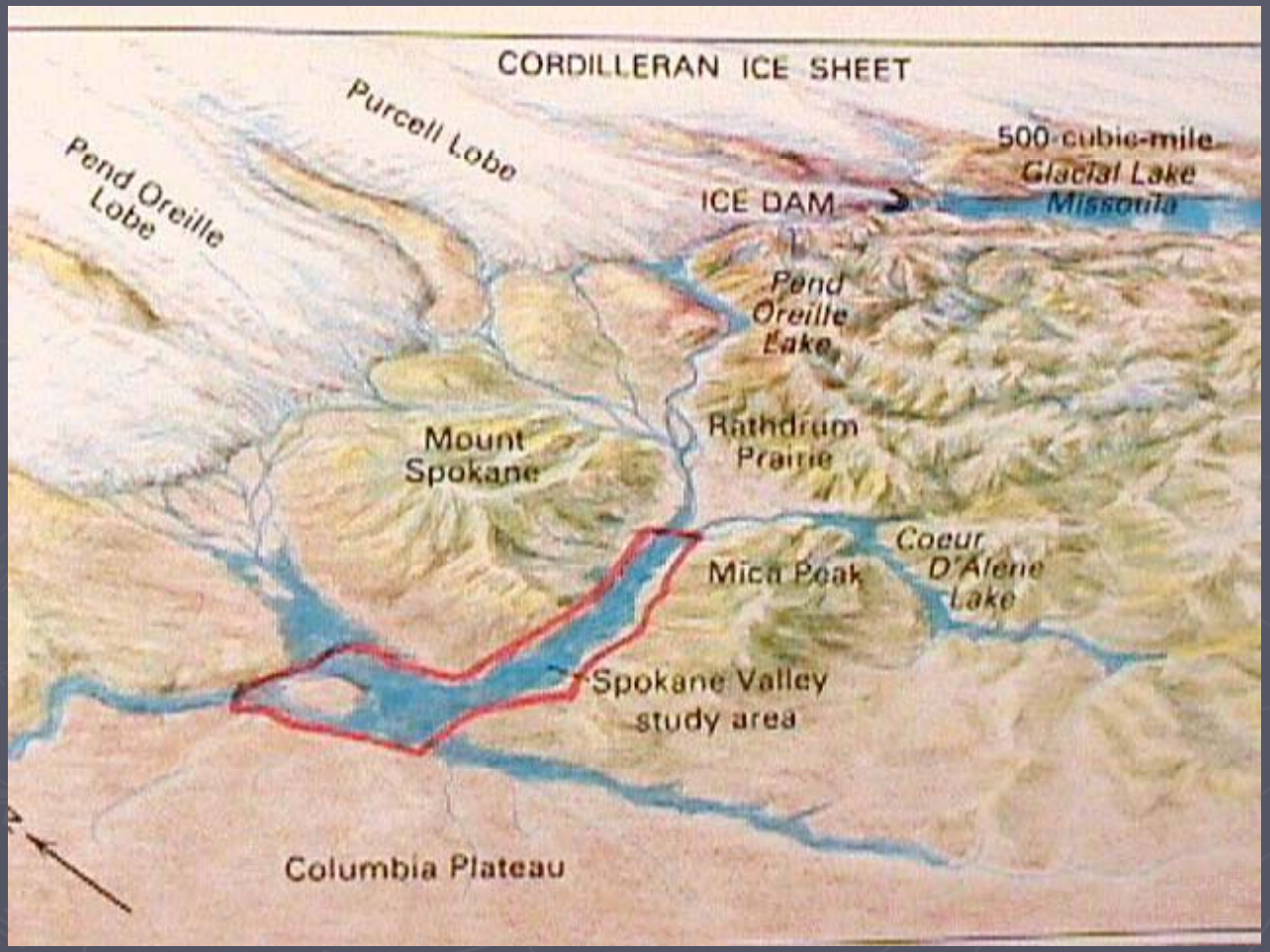
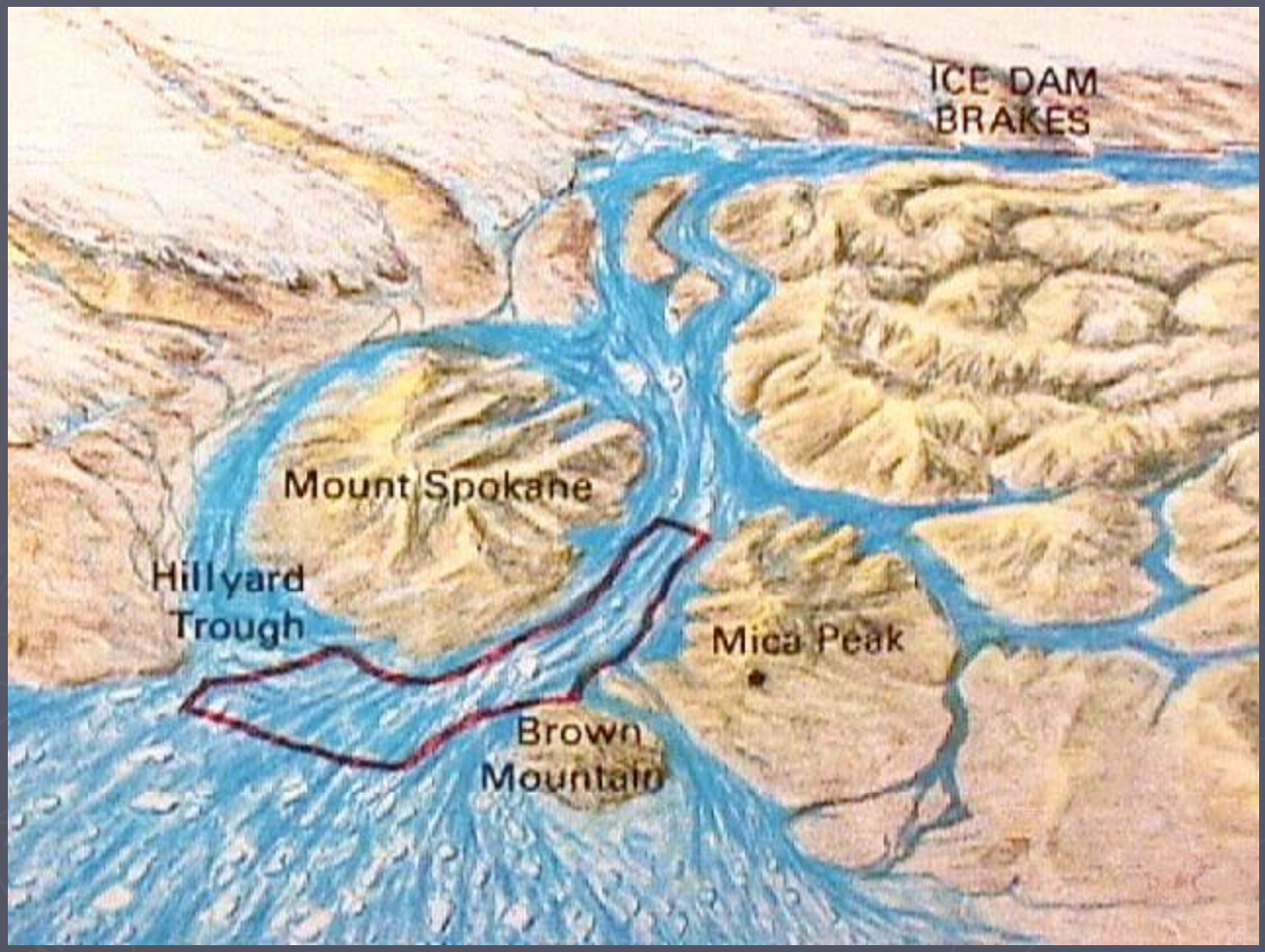
This poster is adapted from the inset of "The Spokane Valley - Rathdrum Prairie Aquifer Atlas", produced by the Spokane County Water Quality Management Program and the Idaho Department of Environmental Quality, August, 2000."

15,000 years ago:





- Molenaar (USGS 1988)



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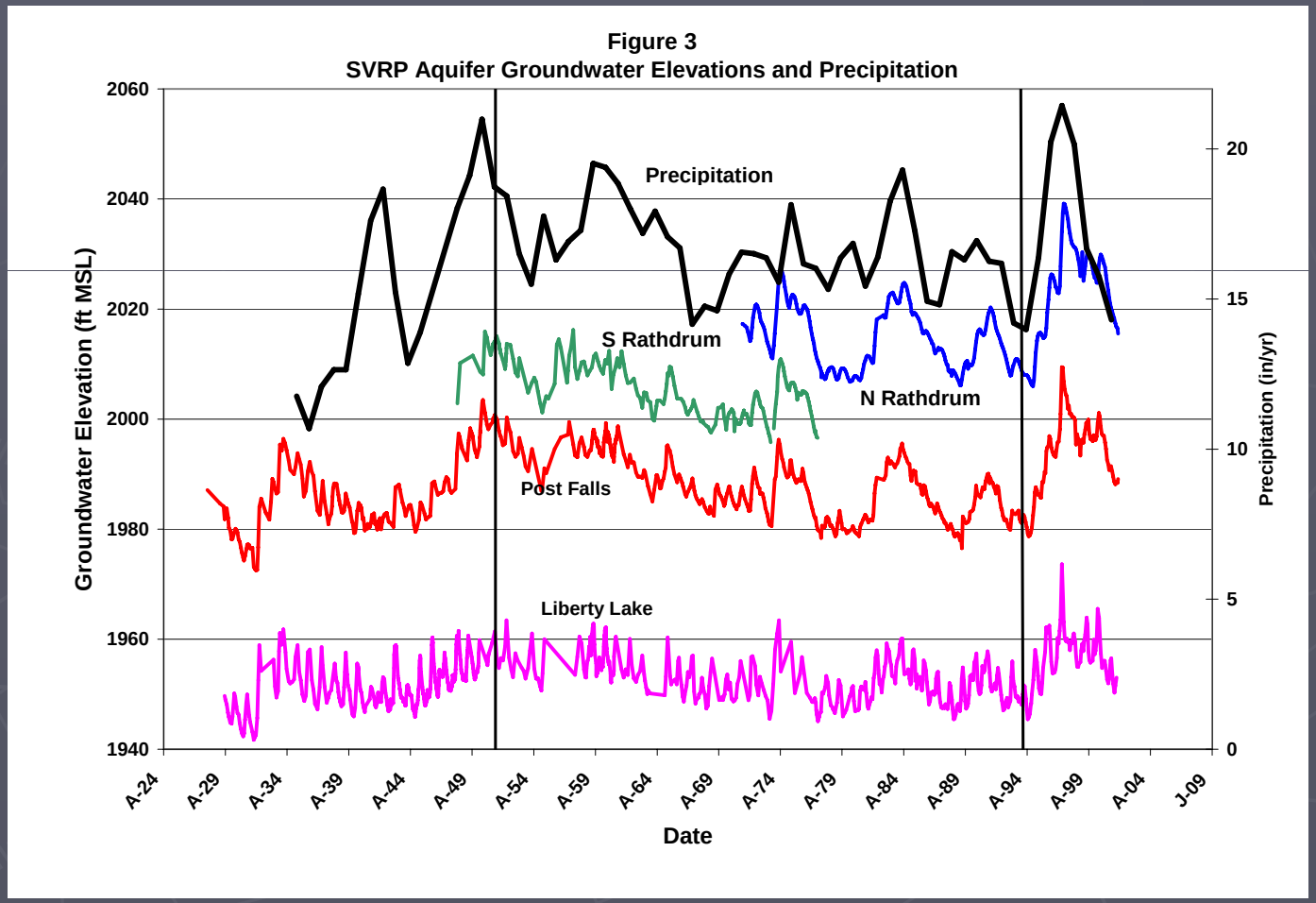
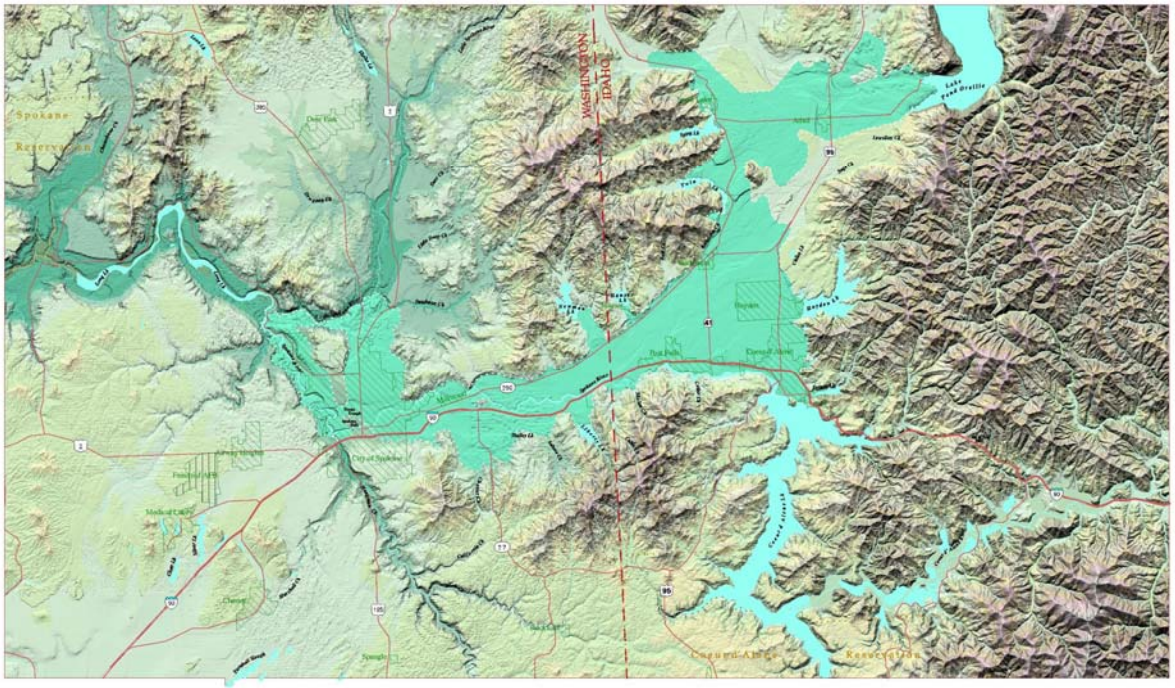


Figure 3
SVRP Aquifer Groundwater Elevations and Precipitation
Groundwater Elevation (ft MSL)
Precipitation (in/yr)
Date
Precipitation
S Rathdrum
N Rathdrum
Post Falls
Liberty Lake
2060
2040
2020
2000
1980
1960
1940
20
15
10
5
0
A-24
A-29
A-34
A-39
A-44
A-49
A-54
A-59
A-64
A-69
A-74
A-79
A-84
A-89
A-94
A-99
A-04
J-09

- Designated sole source in 1978
- 450,000 users
- Motivated by concerns about water quality especially septic system nitrates
- But not quantity



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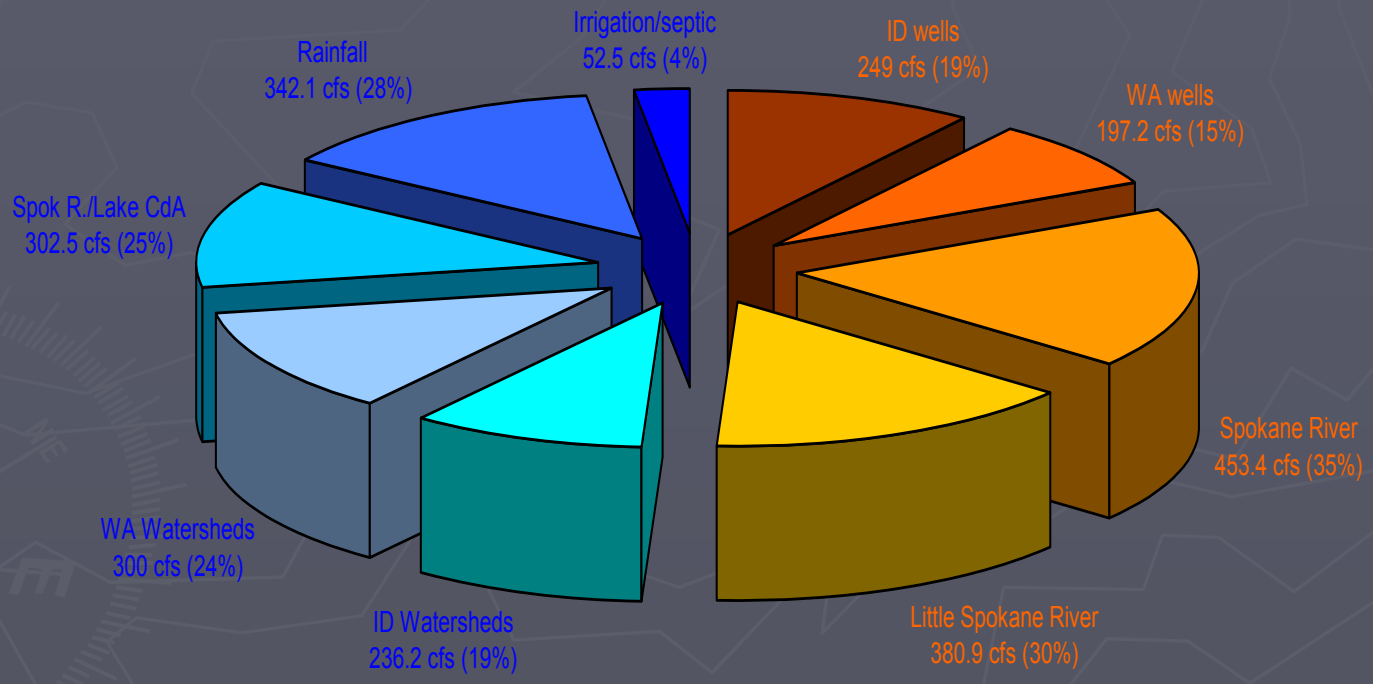
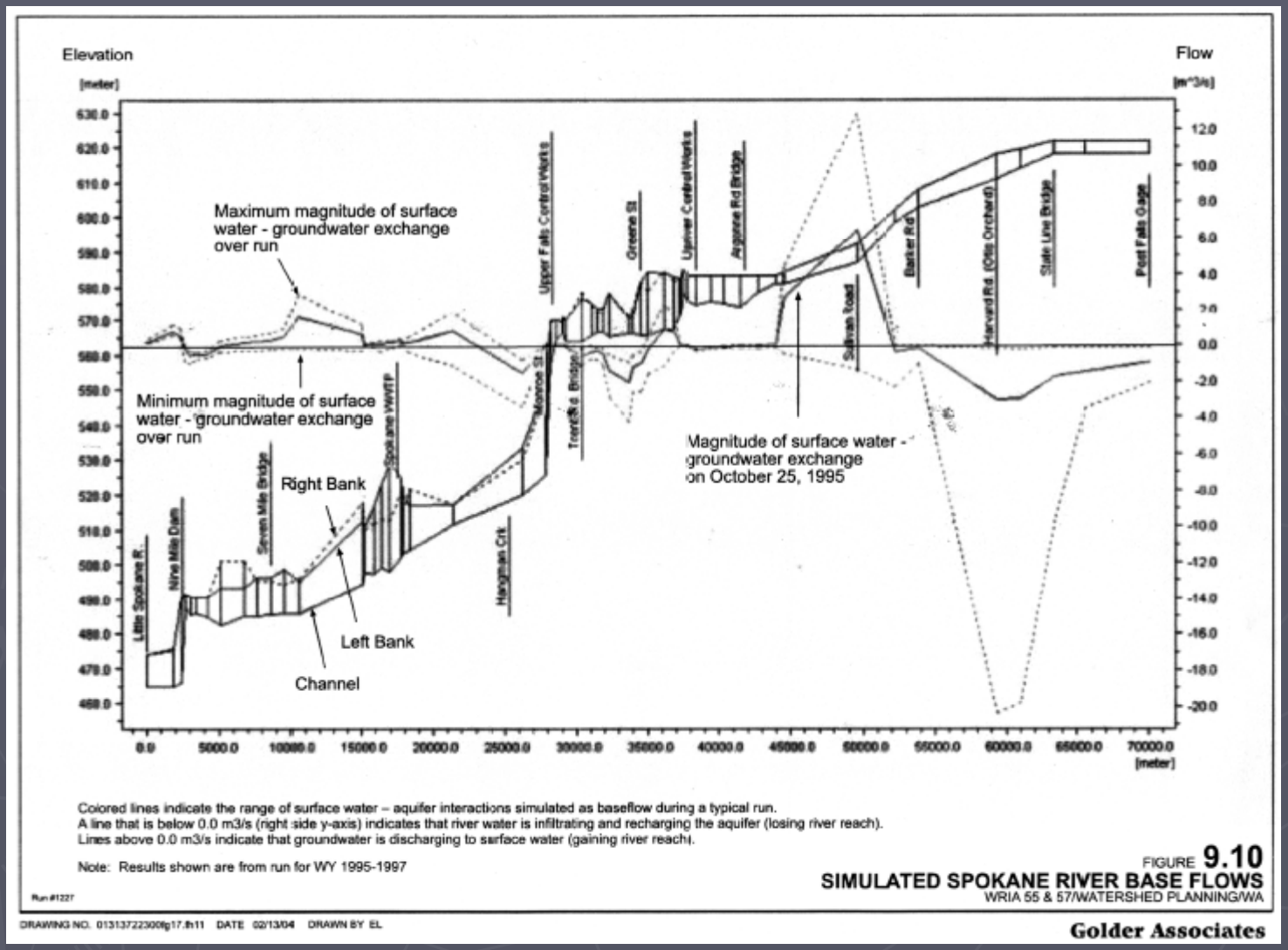
SVRP Recharge-Discharge Components
Current Levels



Recharge & Discharge: Spokane River



Colored lines indicate the range of surface water – aquifer interactions simulated as baseflow during a typical run.
A line that is below 0.0 m3/s (right side y-axis) indicates that river water is infiltrating and recharging the aquifer (losing river reach).
Lines above 0.0 m3/s indicate that groundwater is discharging to surface water (gaining river reach).

Note: Results shown are from run for WY 1995-1997

FIGURE **9.10**
SIMULATED SPOKANE RIVER BASE FLOWS
WRIA 55 & 57/WATERSHED PLANNING/WA

Run #1227

DRAWING NO. 013137223006g17.fh11 DATE 02/13/04 DRAWN BY EL

Golder Associates

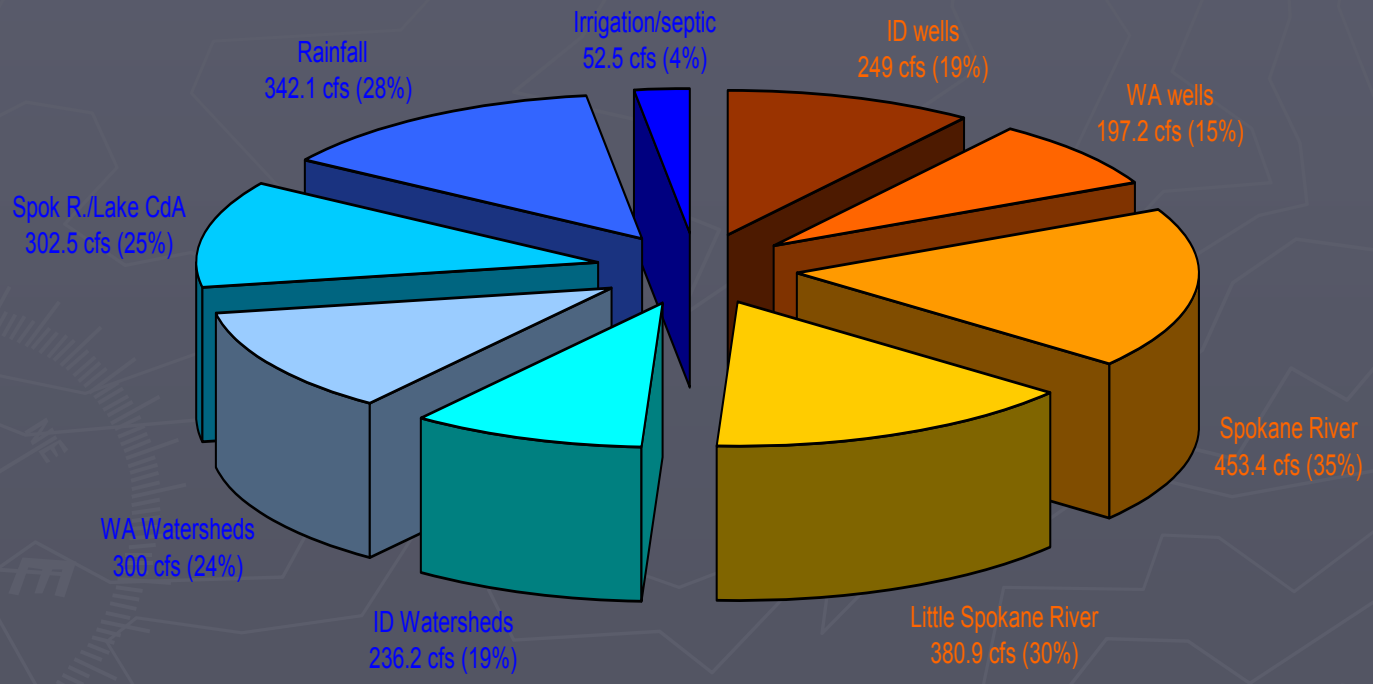
Focusing public attention on quantity

- Energy “crisis” 2001
- Two Rathdrum Prairie power plant proposals
- 20 mgd – 100% consumptive use
- Water right protests
- Applications denied as “contrary to the conservation of water resources in Idaho”

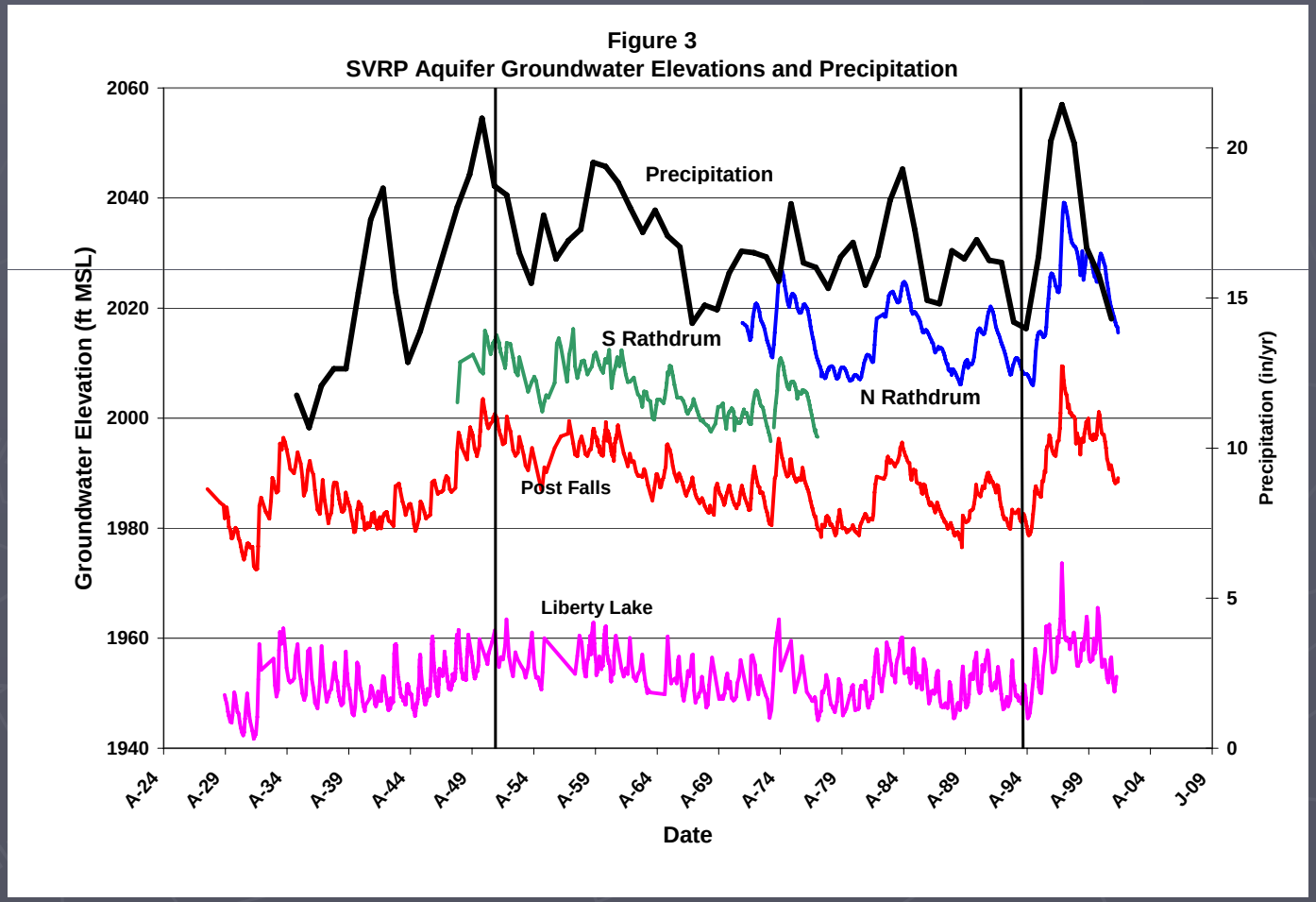
What the power plant hearing officer did not rule:

- That the SVRP Aquifer is fully allocated (in Idaho)
- That pumping from the SVRP Aquifer (in Idaho) depletes Spokane River stream flow (in Washington)

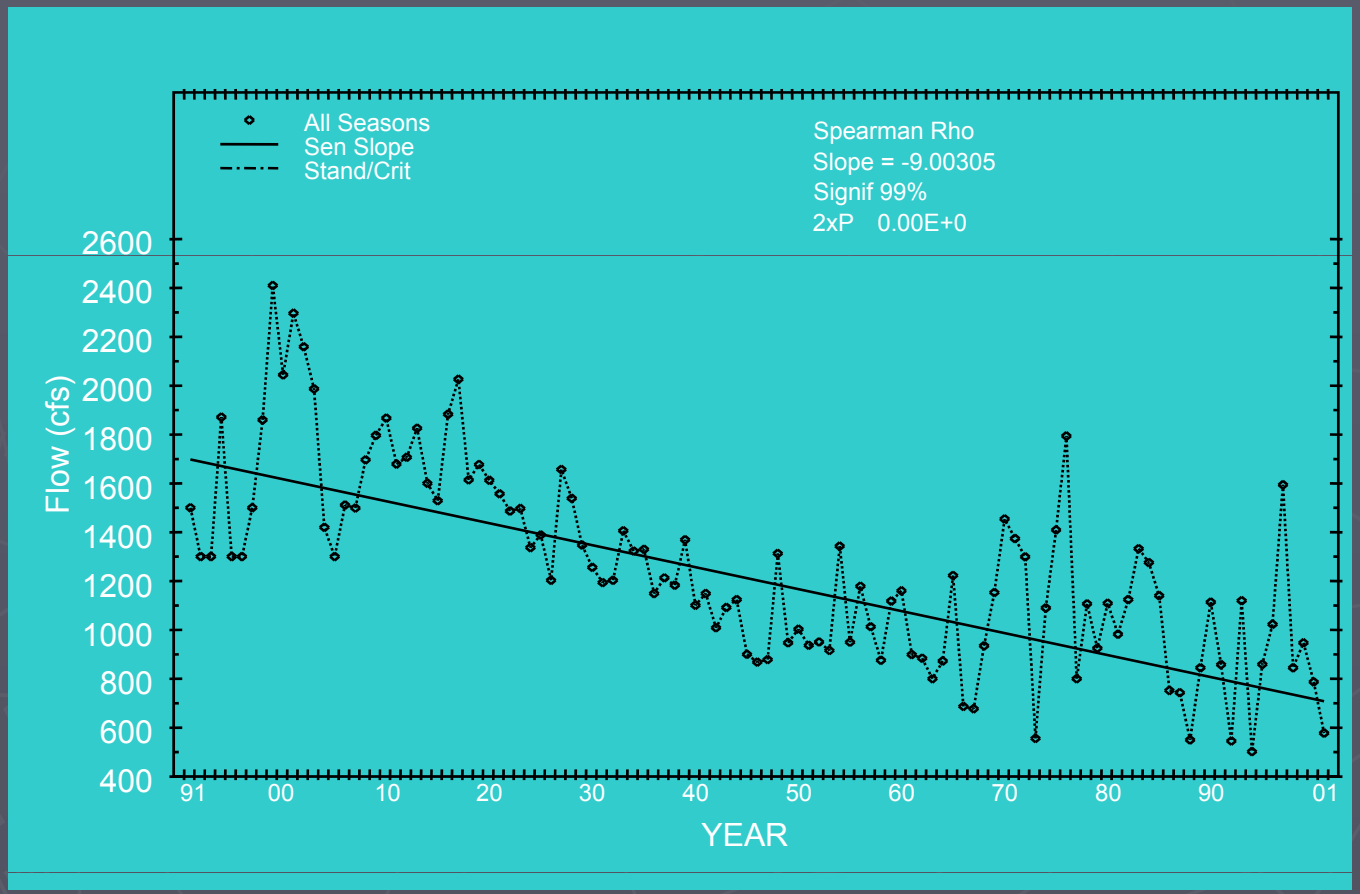
SVRP Recharge-Discharge Components
Current Levels



Water levels are fairly constant



I = O +/- ΔS


All Seasons
Sen Slope
Stand/Crit
Spearman Rho
Slope = -9.00305
Signif 99%
2xP 0.00E+0
Flow (cfs)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
91
00
10
20
30
40
50
60
70
80
90
01
YEAR

Spokane Falls
Labor Day Weekend 2003

Received Law from the Yakima basin

- Hydraulic continuity between ground and surface waters will be recognized
- New ground water rights may be denied if adverse affects on stream flows
- Washington imposes a de facto moratorium on new water rights in mid -1990s

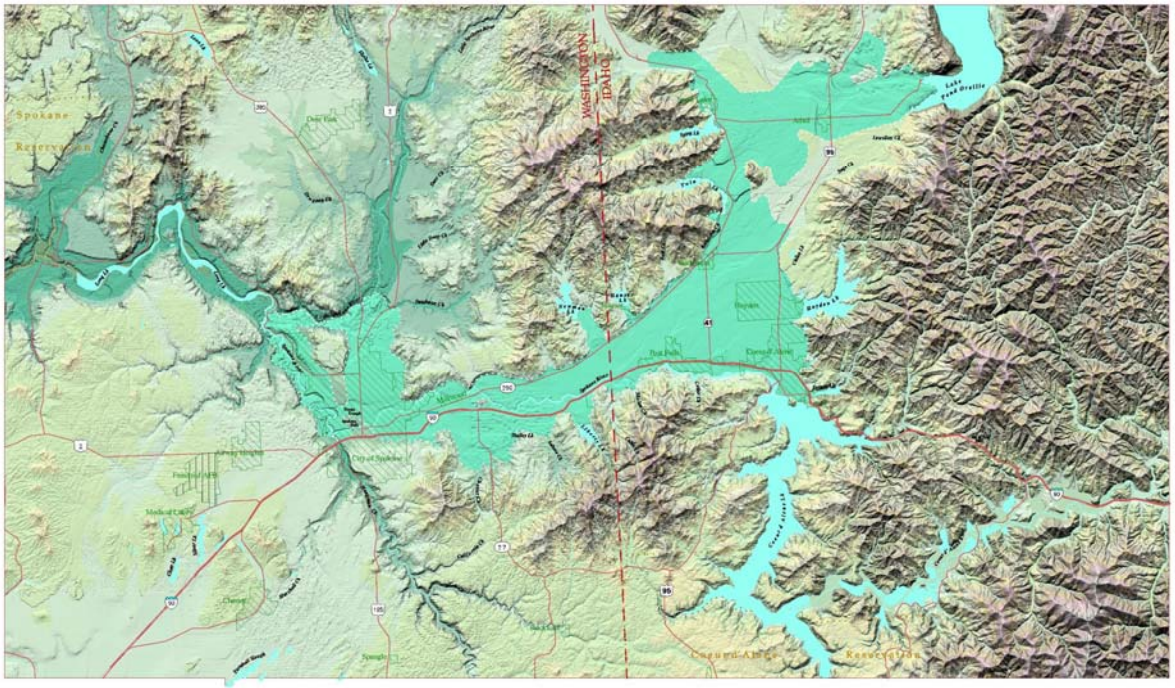
Rathdrum power plants spawn 3 reactions

- Bi-State Aquifer Study
  - To determine aquifer recharge, capacity, use, hydraulic characteristics including Spokane River connections
  - Federally funded
- Petition for moratorium on new groundwater rights in Idaho
  - Not enough is known about the Aquifer, so a moratorium is not appropriate (?)
- Run on water rights
  - Approximately 20 cfs in water rights granted since January 2002 – no analysis of water availability

Idaho & Washington share much in common, water code-wise

- Both are prior appropriation states
- Both require conjunctive use of surface and groundwaters
- Both prohibit mining of aquifers

- But Idaho continues to issue water rights while Washington does not.
- Why?



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Interstate (or Tribal) Compacts:

Should Groundwater Be on the Table?

Yakima basin

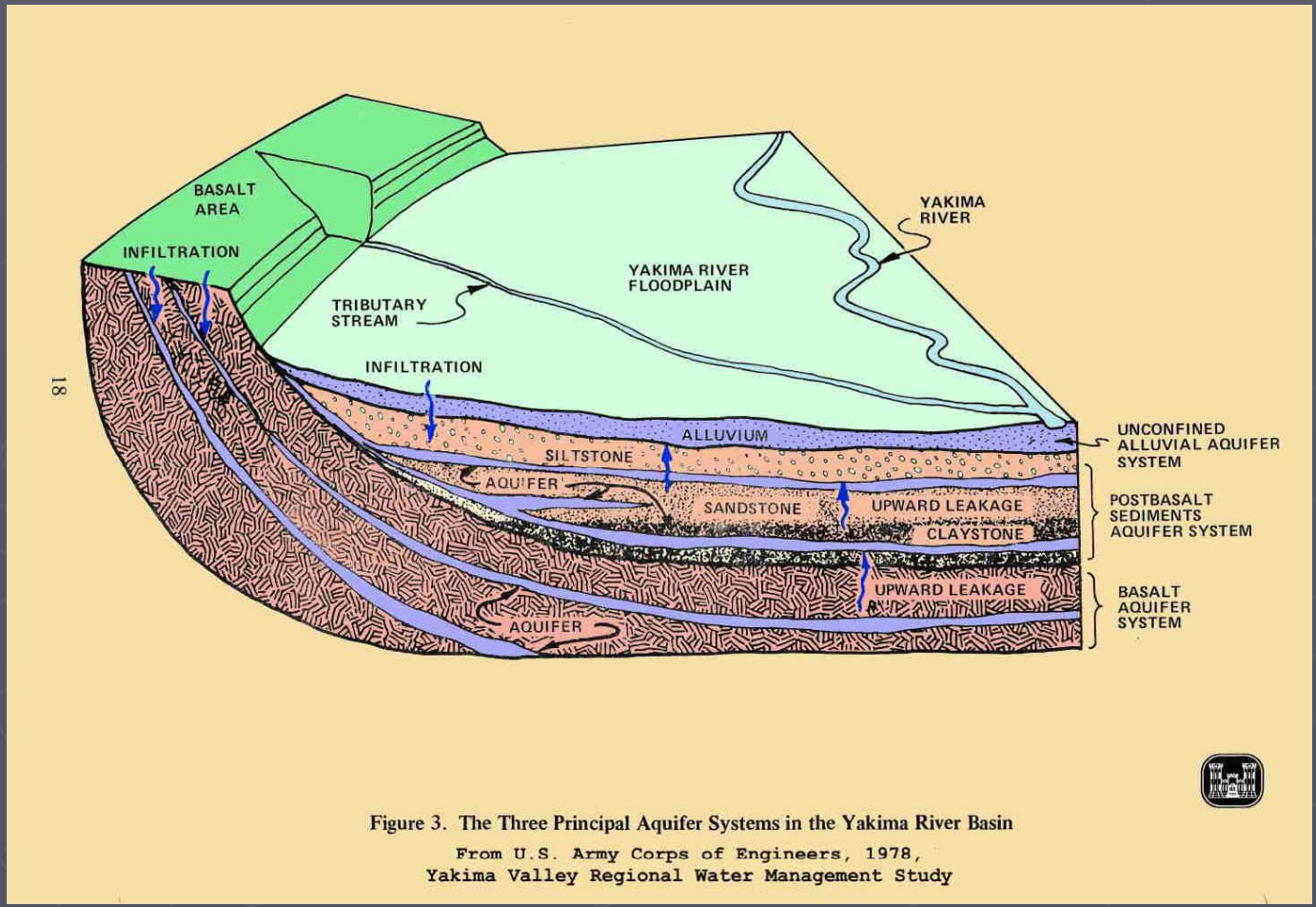
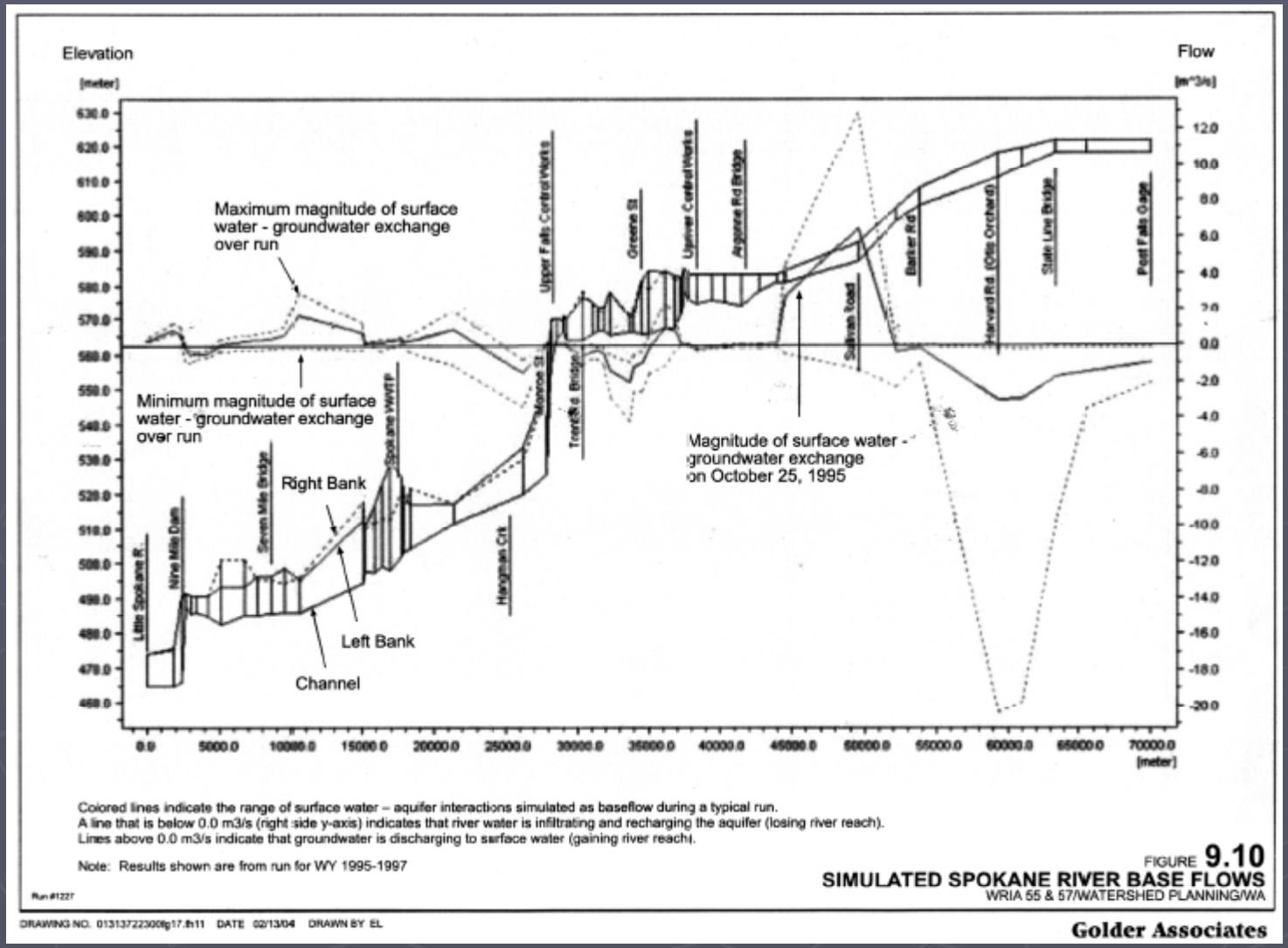


Figure 3. The Three Principal Aquifer Systems in the Yakima River Basin

From U.S. Army Corps of Engineers, 1978,
Yakima Valley Regional Water Management Study



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DRAWING NO. 013137223006g17.fh11 DATE 02/13/04 DRAWN BY EL

Golder Associates

Legal recognition of hydraulic connection between ground and surface waters in the context of sovereign ownership (i.e. reserved rights):

- Cappaert v. U.S. (USSC 1976)
- Colville Confederated Tribes v. Walton (9C 1981)
- U.S. v. Anderson (Spokane Tribe) (9C 1984)
- In Re Gila River III (Ariz. 1999)
- Confederated Salish & Kootenai Tribes v. Stults (Mont. 2002)
- Lummi Nation v. Washington (U.S.D.C. Wa. 2003)

Legal recognition of hydraulic connection between ground and surface waters in the context of compact enforcement:

- Kansas v. Colorado (Arkansas River) (1995, 2001)
- Nebraska v. Wyoming (North Platte) (1995, 2001)
- Kansas v. Nebraska (Republican River (2001)

From Kansas v. Nebraska, Special Master Order (2001):

- "Nebraska's assertion that the Compact does not restrict ground water pumping because it never mentions ground water misses a critical fact: Although the Compact never uses the word 'ground water,' streamflow, which the Compact fully allocates, comes from both surface runoff and ground water discharge.

- Interception of either of those streamflow sources can cause a State to receive more than its Compact allocation and violate the Compact.

- Thus . . . Even without use of the express term 'ground water' . . . As a matter of law, a State can violate the Compact through excessive pumping of ground water hydraulically connected to the Republican River and its tributaries."

- Is any compact safe ?

Sources of inspiration for a new era of water compacting

- Bellagio Draft Treaty
- ASCE's Model Water Sharing Agreements
- U.N. Convention on the Non-Navigational Use of International Watercourses
- Searching Out the Headwaters, Bates et al.

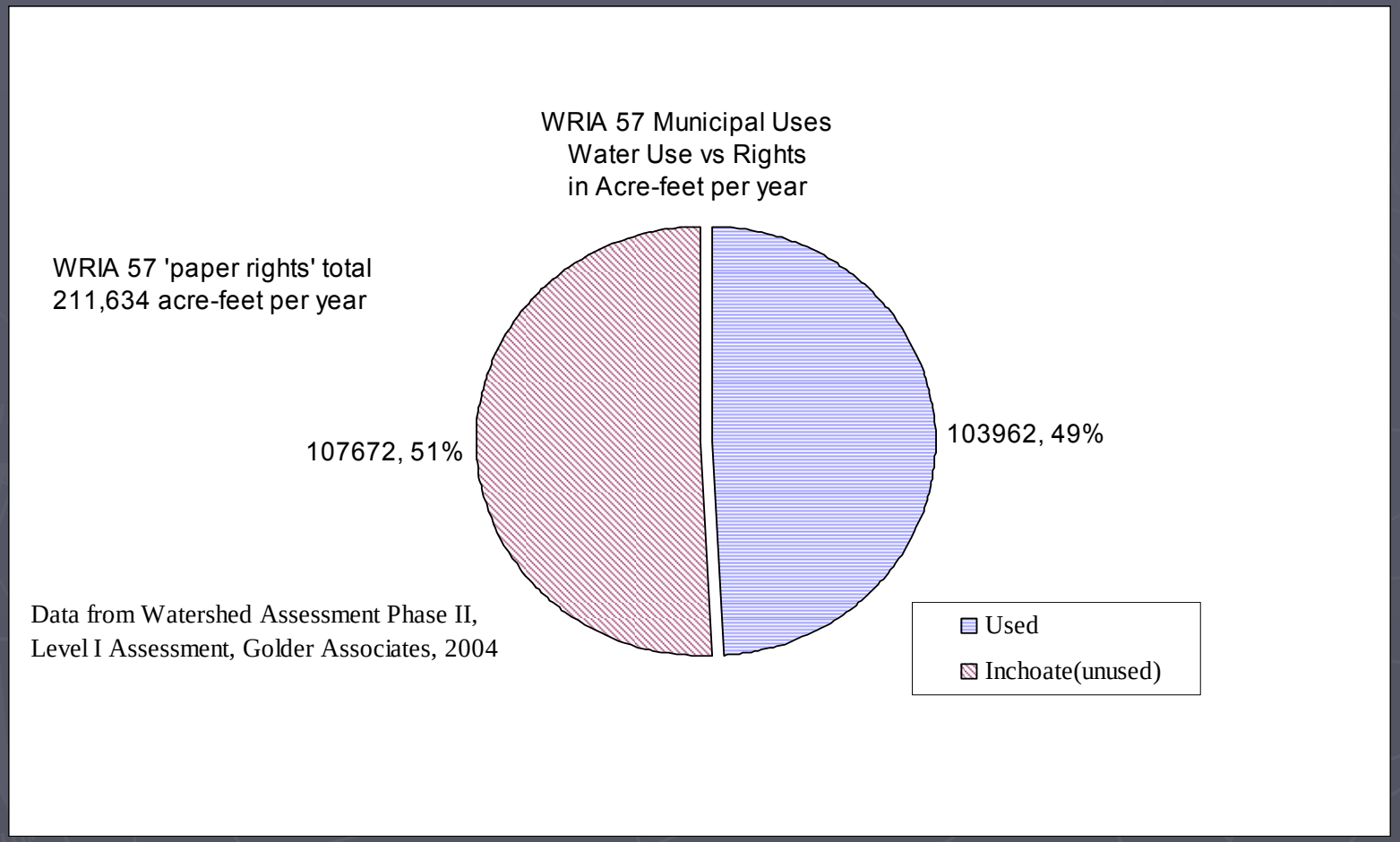
7 fundamentals

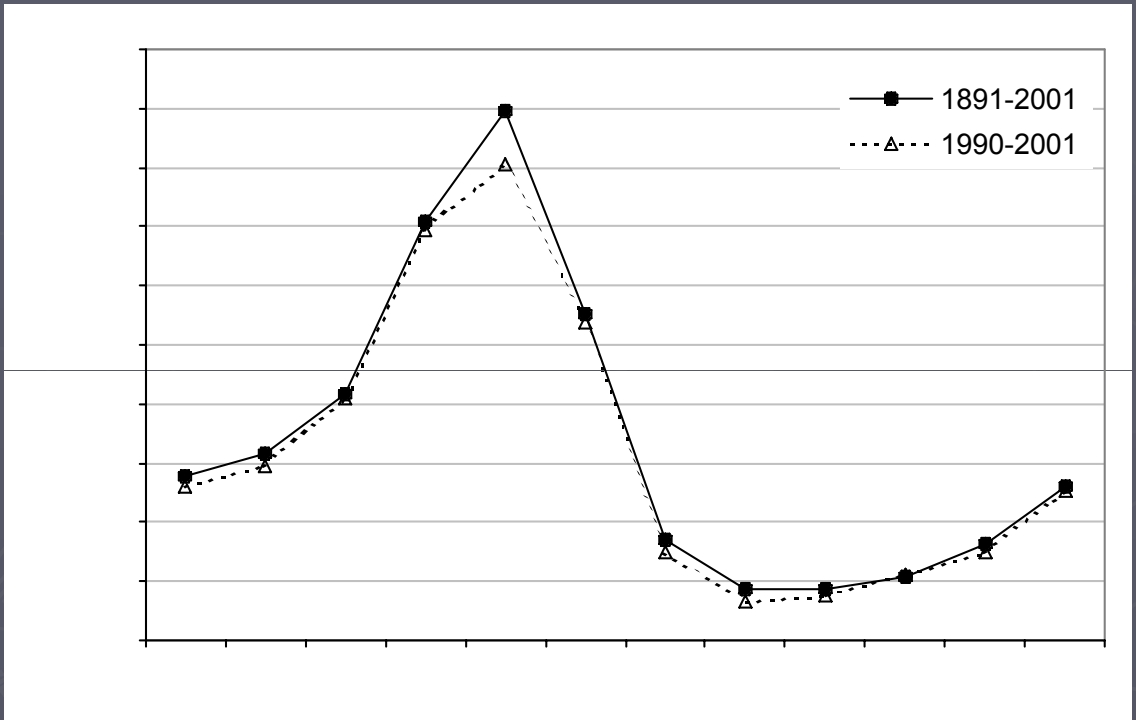
- 1 – Utilize first principles of science
- 2 – A corollary: integrate ground and surface water management
- 3 – Integrate water quantity & quality management
- 4 – Acknowledge groundwater as a public trust resource and utilize the precautionary principle
- 5 – Embrace the restoration model
- 6 – Future flexibility
- 7 – Include all sovereigns – ie, the tribes

Spokane Valley-Rathdrum Prairie Aquifer springs flowing into the Spokane River

and just downstream . . .

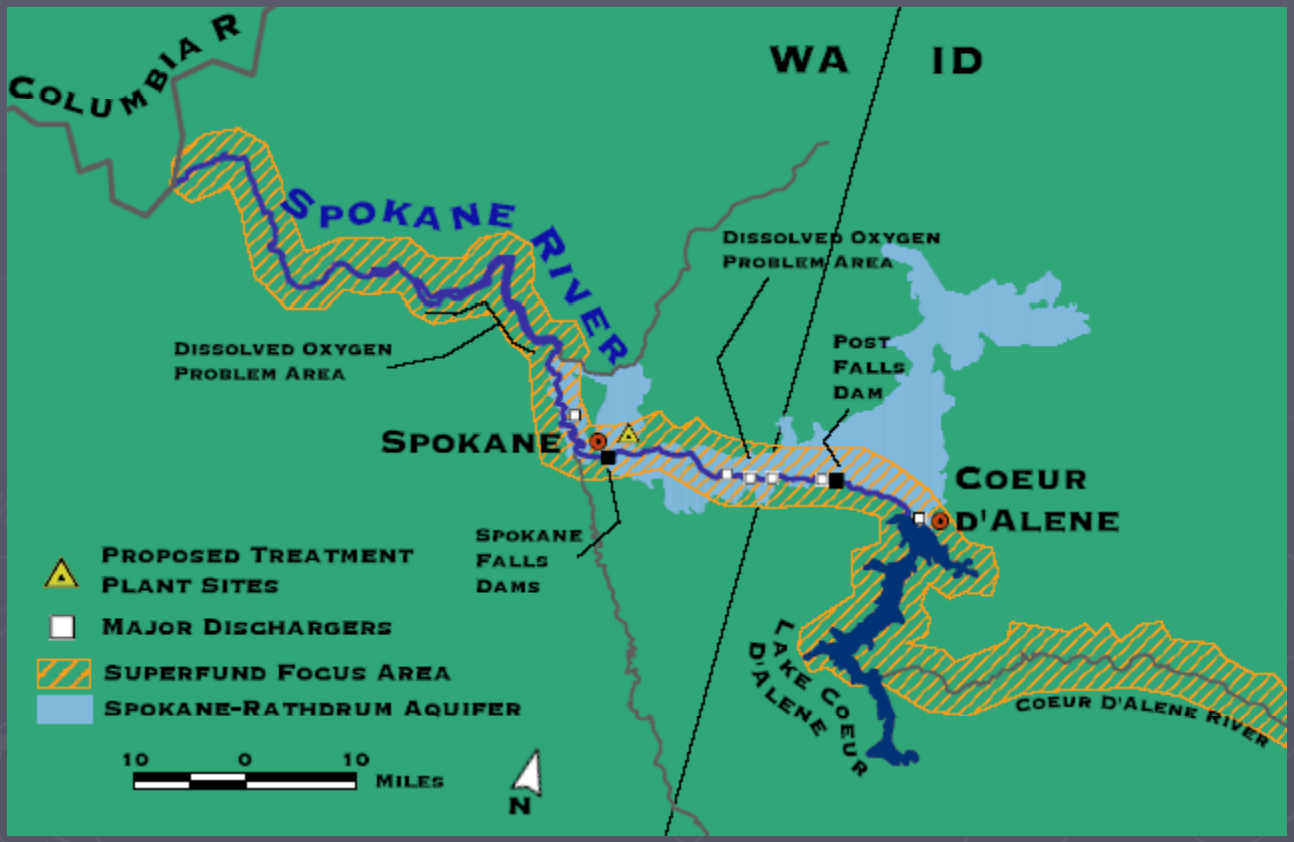
Another Problem: Paper water rights





- Hydrograph of the monthly mean flow between 1891-2001 and 1990-2001 for the Spokane River below the Monroe Street Dam (*Source*: USGS 12422500)

Spokane River Water Quality Highlights



- American Rivers 2004

Yakima basin streamflow

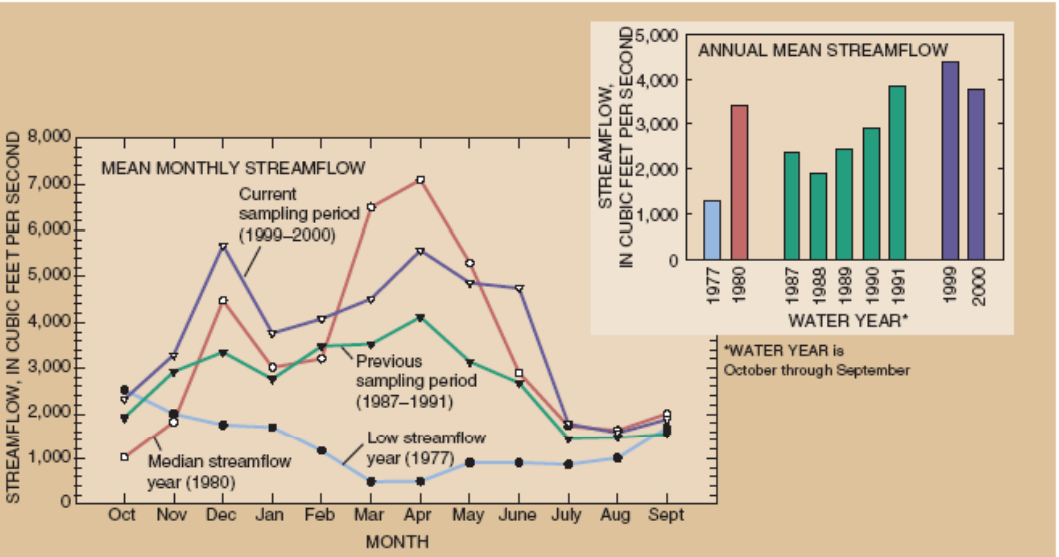


Figure 2. The amount of water measured near the mouth of the Yakima River can vary greatly from year to year. In early spring, the streamflow reflects the quantity of water stored in the High Cascades snowpack, while during the dry summer months it reflects the quantity of water released from the basin's storage reservoirs.

Streamflow can have a large effect on water quality

waterways. Therefore, water availability and potential dilution effects must be

sampling period were generally higher than those of the previous sampling

- USGS, Water Quality in the Yakima Basin 1999-2000 Circular No. 1237

Streamflow vs. nitrate concentrations

Sulphur Creek Wasteway, for example, have decreased—especially during 1999 and 2000 [7]. These improvements in water quality support the continued implementation of BMPs. Similar improvements in water quality were not, however, noted in the Yakima River during 1997–2000 [7]. Because of its larger size, it may take longer to improve than the smaller drains and tributaries. Alternatively, annual differences in flow in the Yakima River may mask improvements in water quality. Although it may be somewhat early to see the full extent of improvements in water quality from the BMPs implemented thus far, the 1999–2000 suspended sediment and total phosphorus data are encouraging (fig. 8).

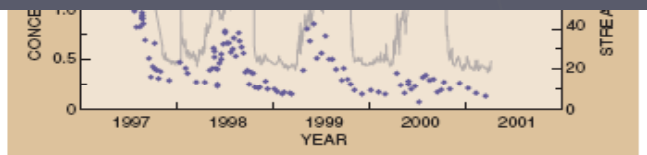
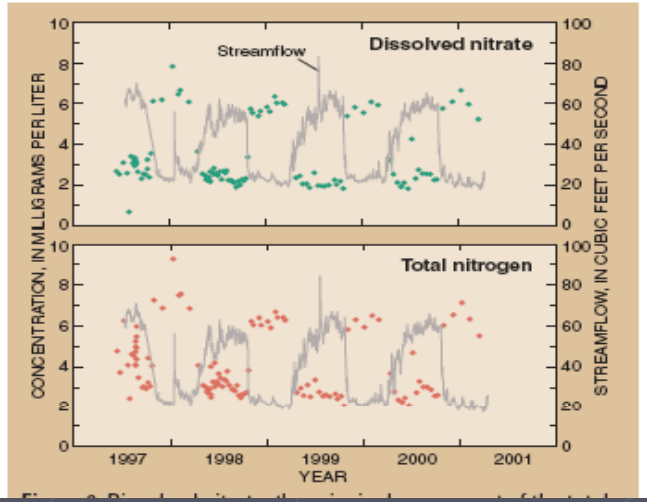


Figure 8. Concentrations of suspended sediment and total phosphorus in Granger Drain show slight decreases since 1997 that may correspond with the increased use of agricultural BMPs in the Granger Basin. Data provided by the Roza-Sunnyside Board of Joint Control (RSBOJC).

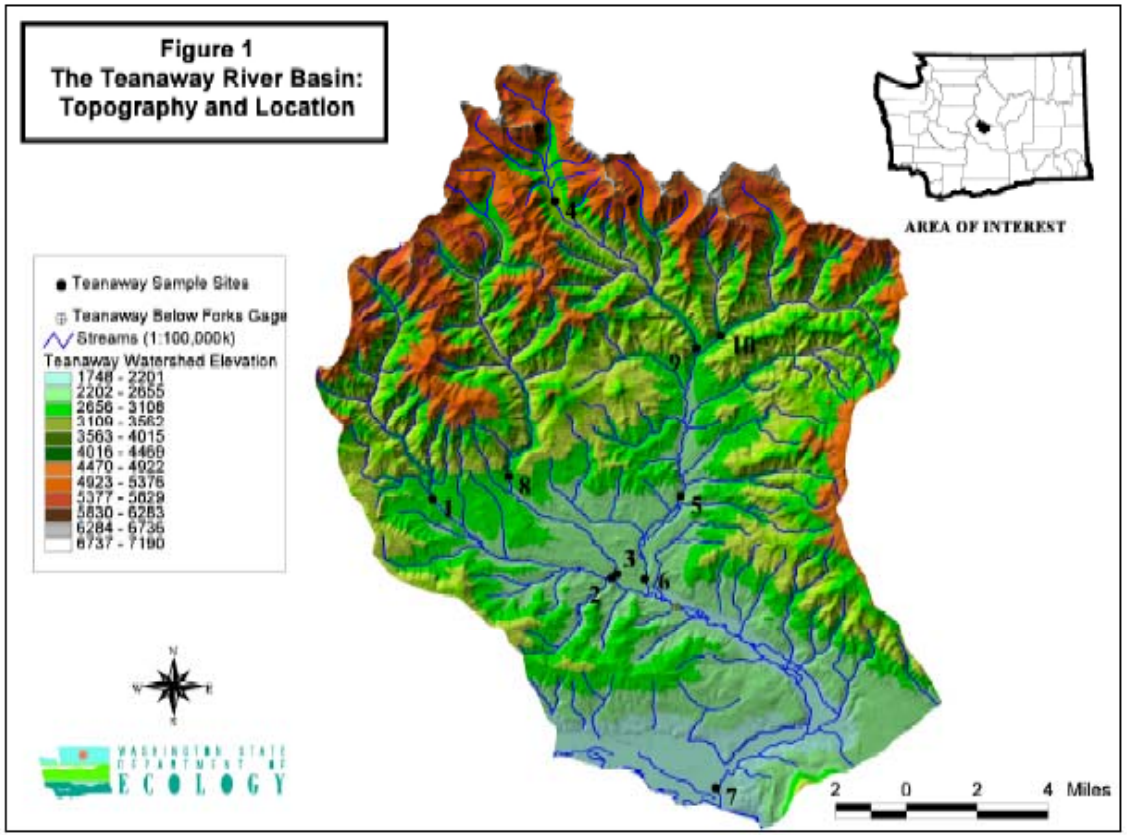
BMPs are needed to reduce nitrate contamination in ground water

Concentrations of nitrate in the agricultural drains and streams were high, especially after the irrigation season, when ground-water discharges dominate flow in the drains. Concentrations of dissolved nitrate in Granger Drain have increased over the period 1991–2000 [7]. Most BMPs are designed to control erosion and therefore aim to reduce the transport of sediment and pollutants associated with sediment such as phosphorus and DDT. Such BMPs are less effective in controlling the movement of water-soluble agricultural pollutants such as nitrate and dissolved pesticides, which leach into ground water during the irrigation season. As a result, despite the implementation of BMPs, reductions in concentrations of nitrate have not yet occurred (fig. 9). Some farmers are now using soil-moisture monitors to prevent over-



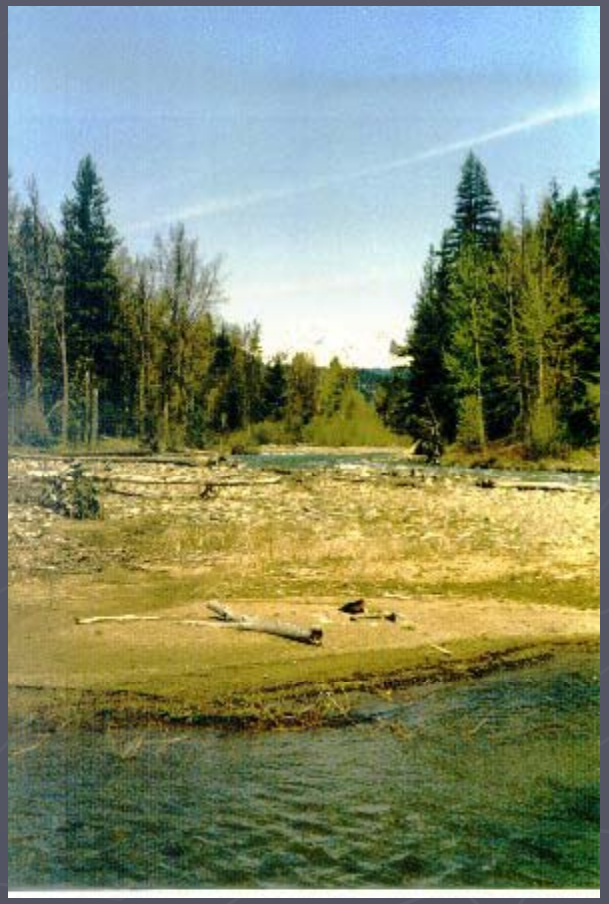
- USGS, Water Quality in the Yakima Basin 1999-2000 Circular No. 1237

Teanaway River – tributary to Yakima River

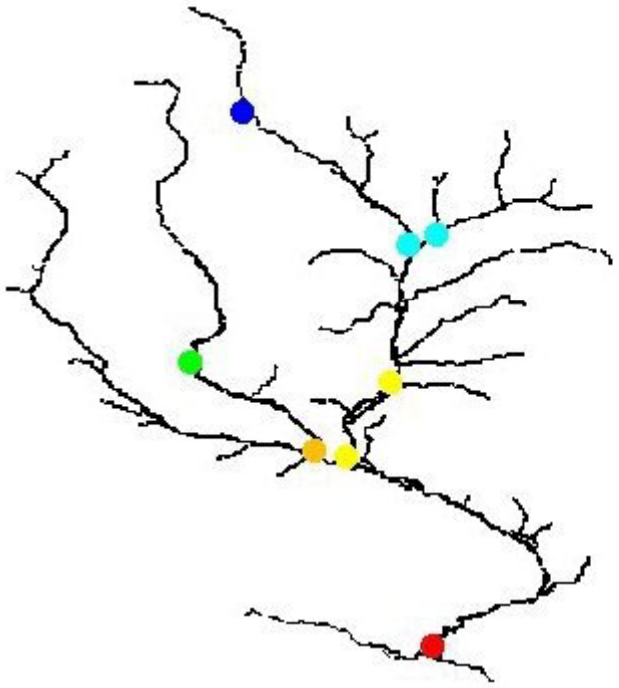


- The Teanaway River system represents some of the highest quality streams and cold-water fish spawning and rearing areas in the Yakima River Basin.

- Under state standards, temperatures should not exceed 16 C (61 F) in the upper reaches and 18 C (64 F) in the lower reaches of the river.



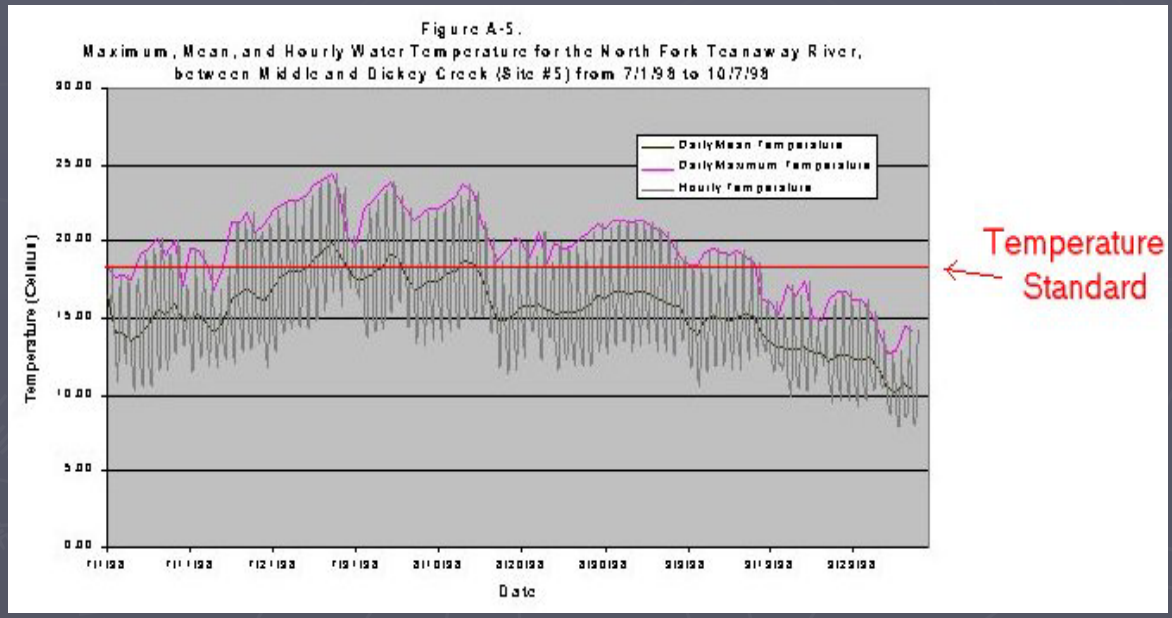
Teanaway Basin River Temperatures



Water Temperature
(Average Daily Maximum)
July 22 to August 11, 1998

12°C	(54°F)
18°C	(64°F)
20°C	(68°F)
23°C	(73°F)
25°C	(77°F)
26°C	(79°F)

Hourly Water Temperatures for the North Fork Teanaway River: July - September, 1998 (WA Dep't of Ecology TMDL website 2004)

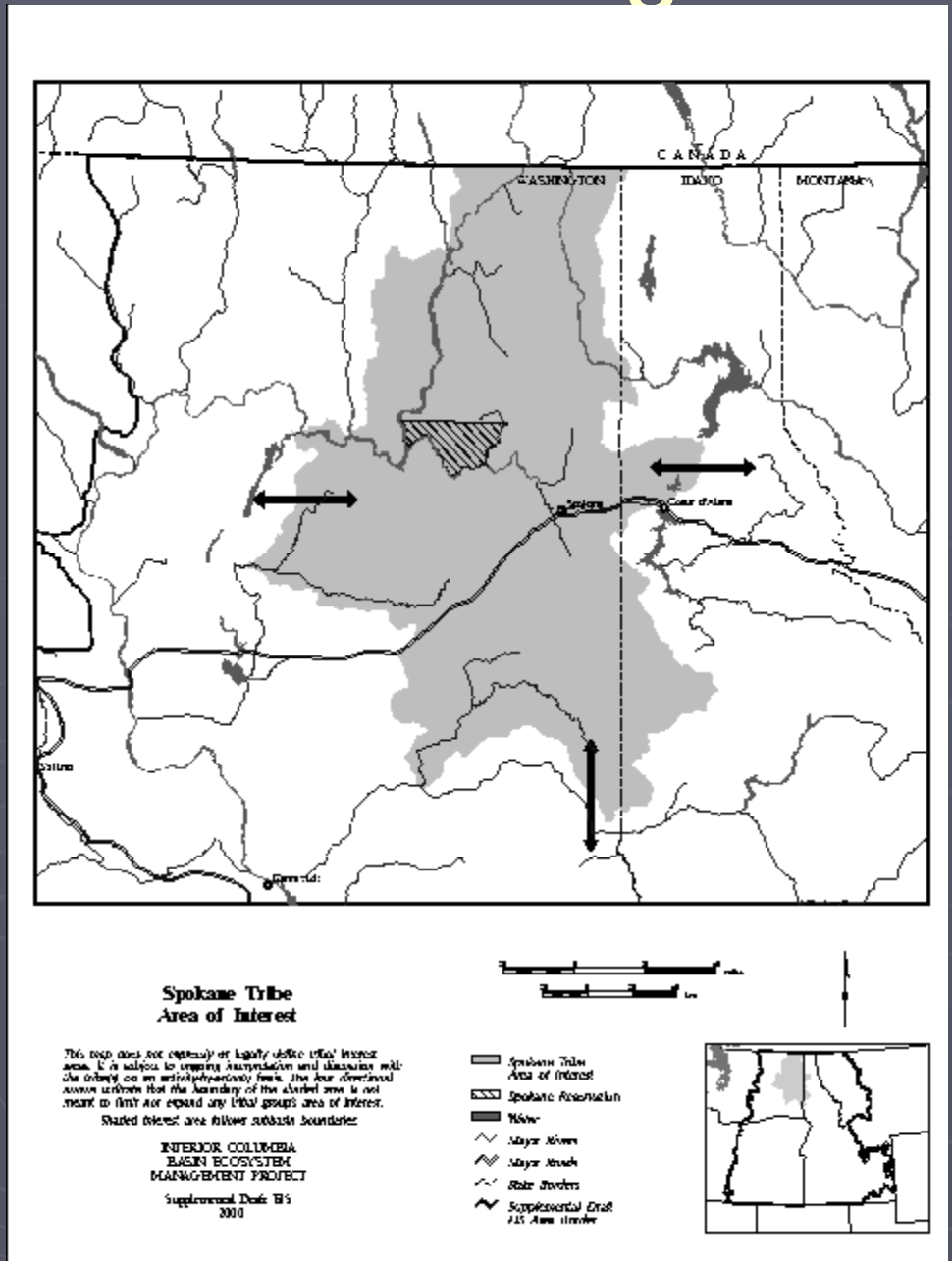


Teanaway River Temperature TMDL Pilot Technical Assessment (2000) Recommendations

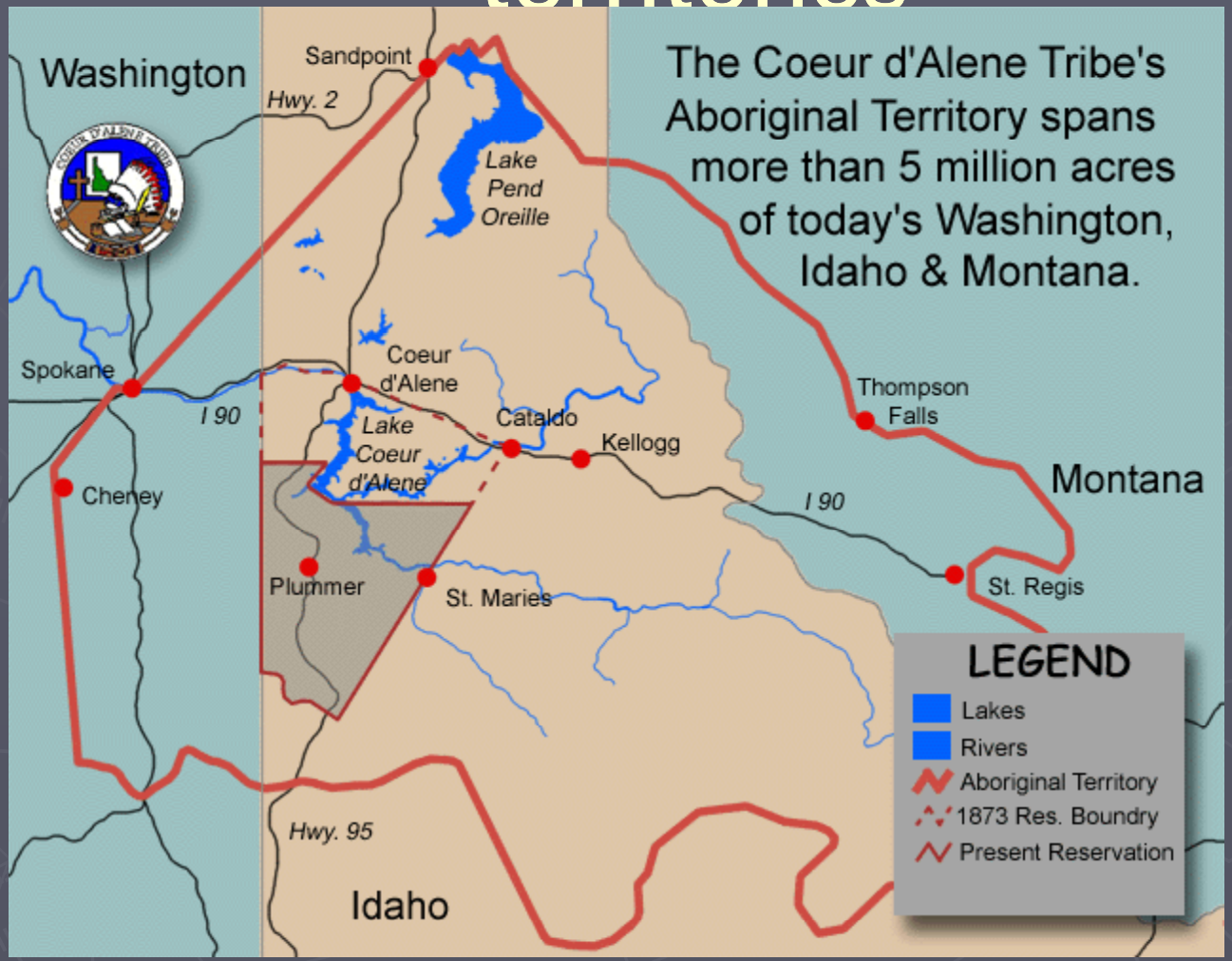
- *Continue water right buyback transactions that have occurred to date.* A larger volume of water cannot be heated as quickly as a smaller one, and a larger volume can assimilate more heat load for the same rise in temperature than a smaller one. *Streamflow levels in the basin will be an important component of temperature control.*

- *When making water permitting and development decisions, consider the negative impacts of withdrawing groundwater that may otherwise be cooling the stream during the summer.*

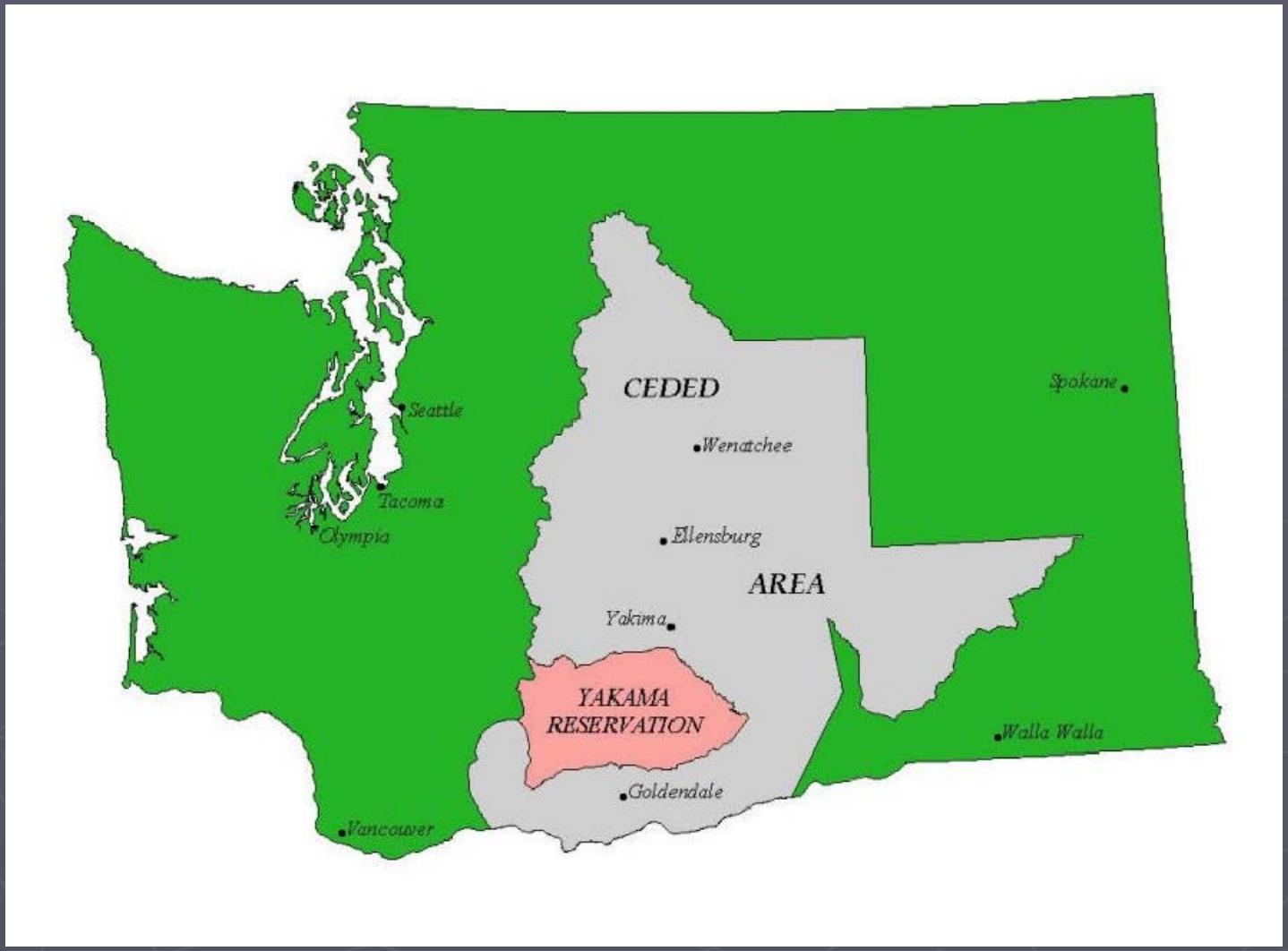
Spokane Tribe aboriginal territories



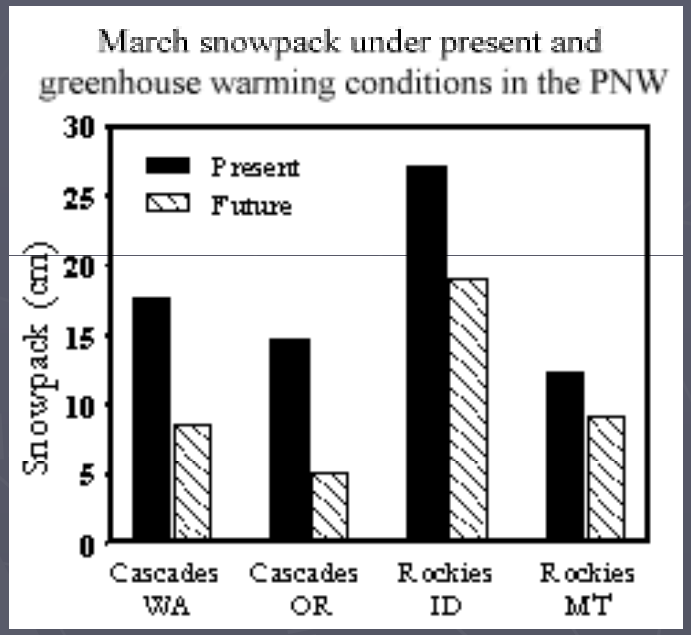
Coeur d'Alene Tribe aboriginal territories

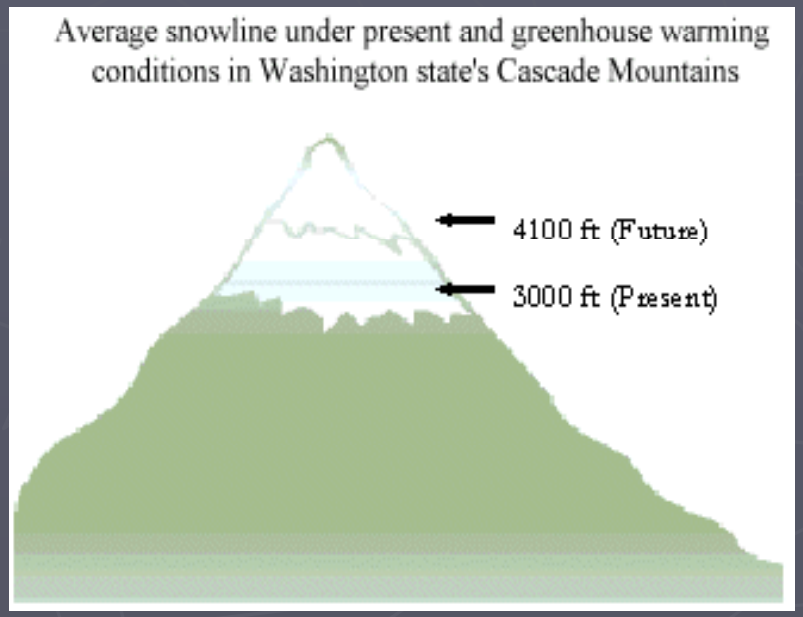


Yakama Nation aboriginal territories

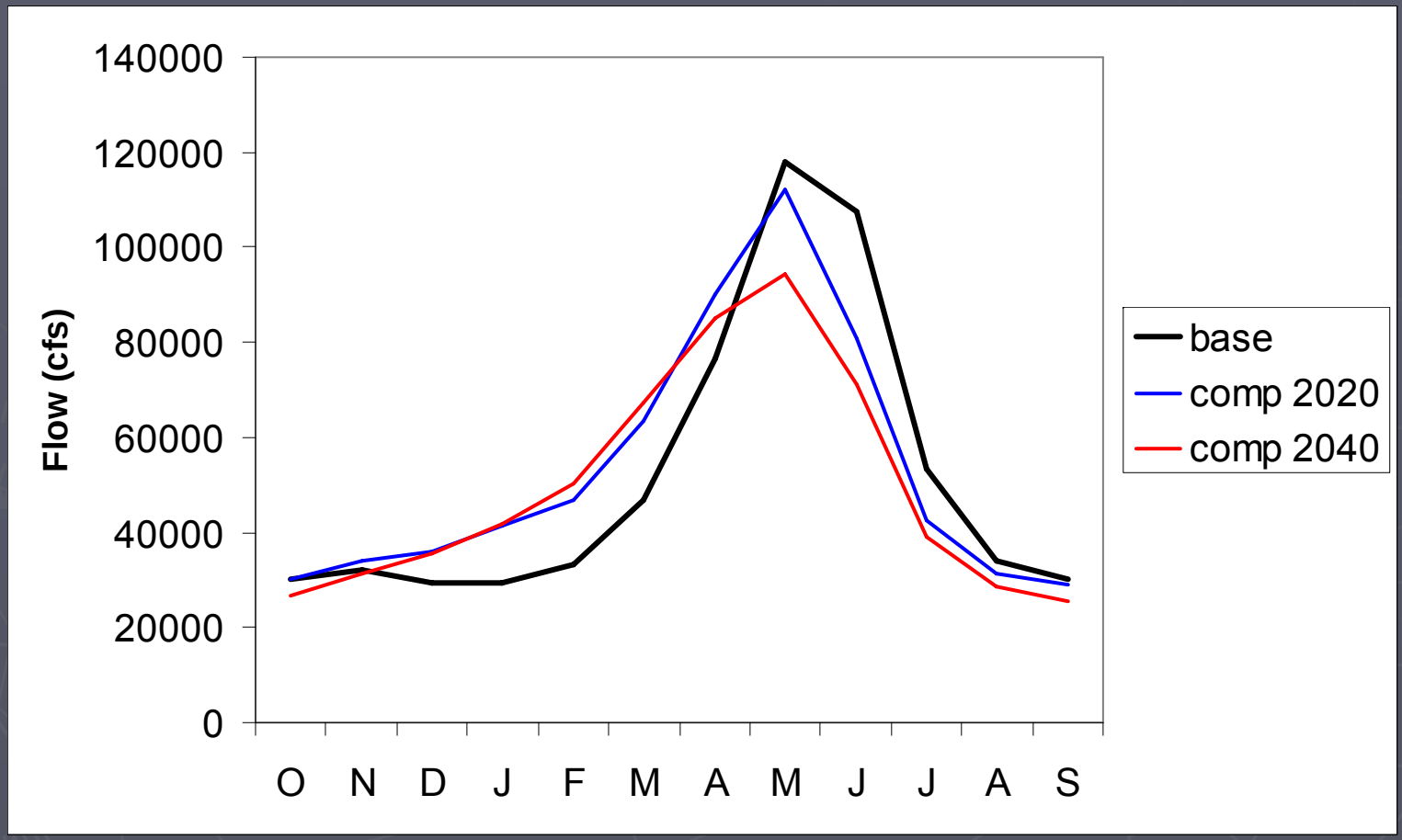


No. 7: Anticipate Managing for Future Uncertainty





- Pacific Northwest National Labs (2001)


140000
120000
100000
80000
60000
40000
20000
0
Flow (cfs)
O
N
D
J
F
M
A
M
J
J
A
S
base
comp 2020
comp 2040

Component	Location	Value (cfs)
ID-Recharge	Watersheds[1]	236.2
	Spokane River/Lake CdA[1]	230
	Rainfall[1]	250
	Total	**716.2**
ID-Discharge	Stateline[2]	457
	Wells[3]	249 (645.5)
	Total	**706**
WA-Recharge	State Line[2]	457
	Basins[4]	300
	Irrigation/septic[4]	52.5
	Spokane River[5]	72.5
	Rainfall[6]	92.1
	Total	**974.1**
WA-Discharge	Spokane River[5]	453.4
	Little Spokane River[7]	380.9
	Wells[8]	197.2 (320.2)
	Total	**1031.5**